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(54) SOUND REDUCTION DEVICE FOR ROCKING PISTON PUMPS AND COMPRESSORS

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(51) **Int. Cl.**

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F04B 53/00	(2006.01)
F04B 39/12	(2006.01)

(52) **U.S. Cl.**

CPC ***F04B 39/0027*** (2013.01); ***F04B 39/0061*** (2013.01); ***F04B 39/12*** (2013.01); ***F04B 53/001*** (2013.01)

(58) **Field of Classification Search**

CPC Y10S 181/403; F04B 39/0061; F04B 39/0027; F04B 39/005; F04B 39/12; F04B 53/001

See application file for complete search history.

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Primary Examiner — Dominick L Plakkoottam

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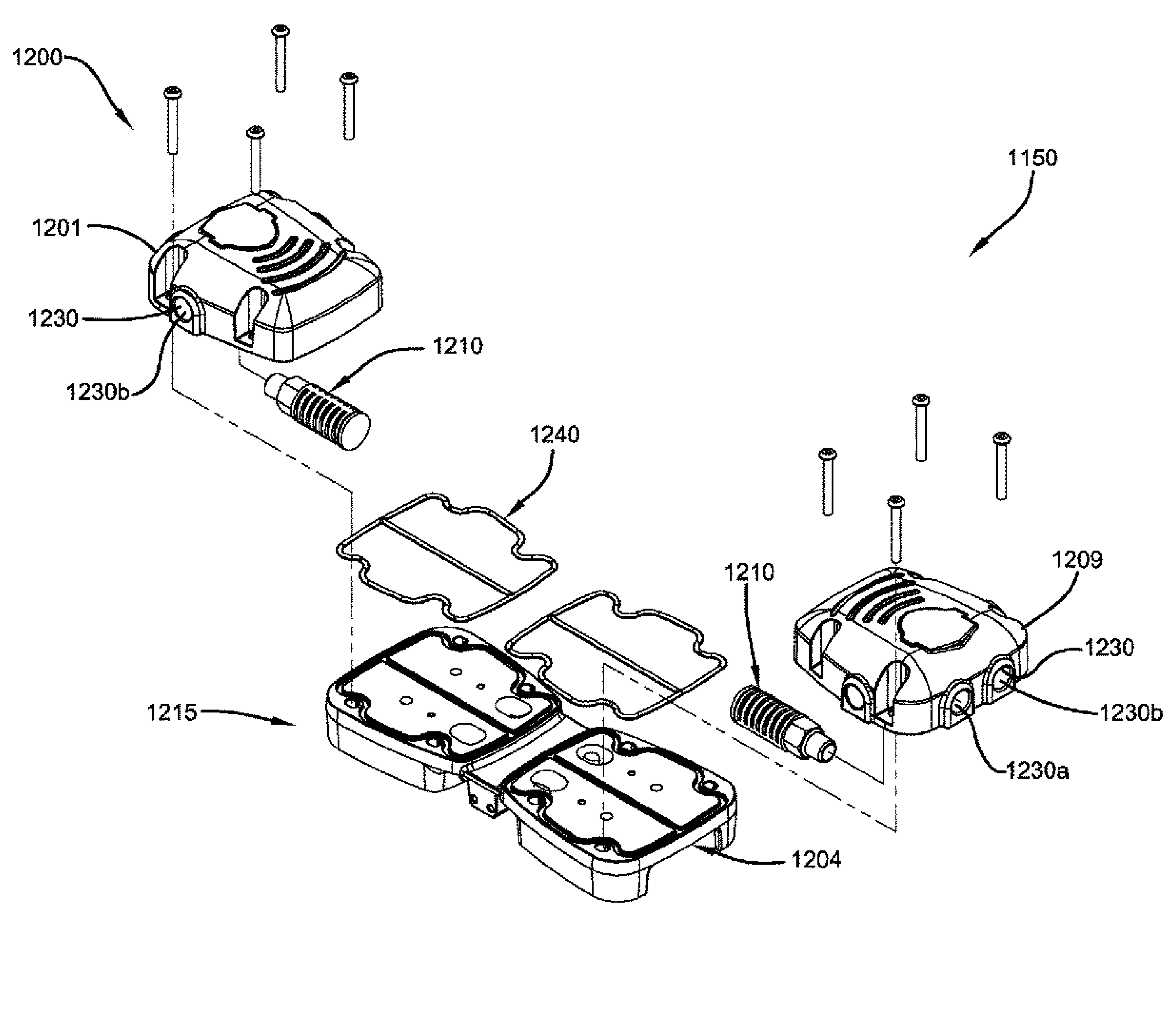
(57) **ABSTRACT**

A rocking piston vacuum pump or compressor may have a sound attenuation assembly. The sound attenuation assembly may comprise a sound attenuation chamber. The chamber may have a first silencer disposed therein with sound dampening foam disposed therein. A second silencer may be disposed in series relative to the first silencer and may be disposed externally of the sound attenuation chamber.

15 Claims, 22 Drawing Sheets



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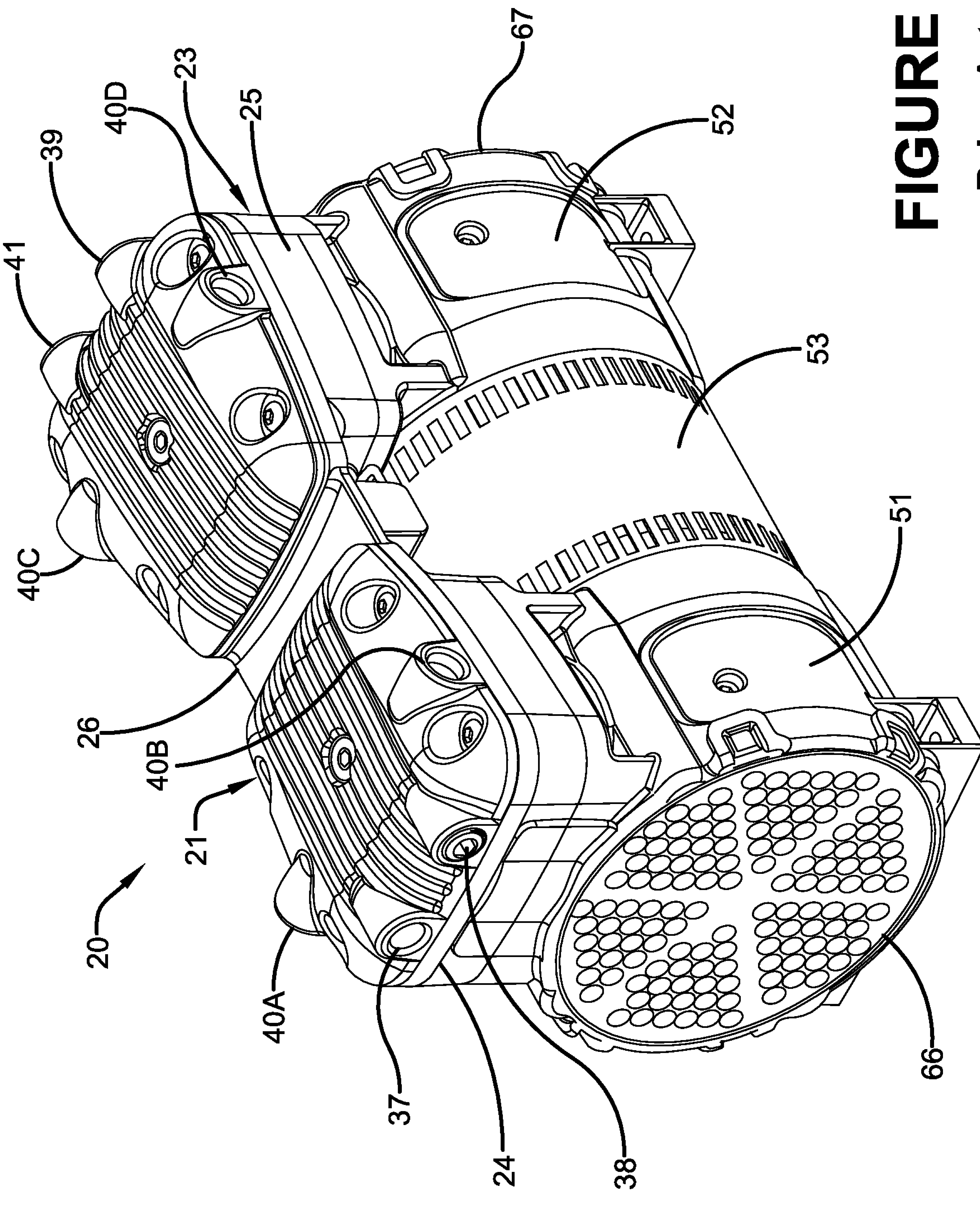

FIGURE 1
Prior Art

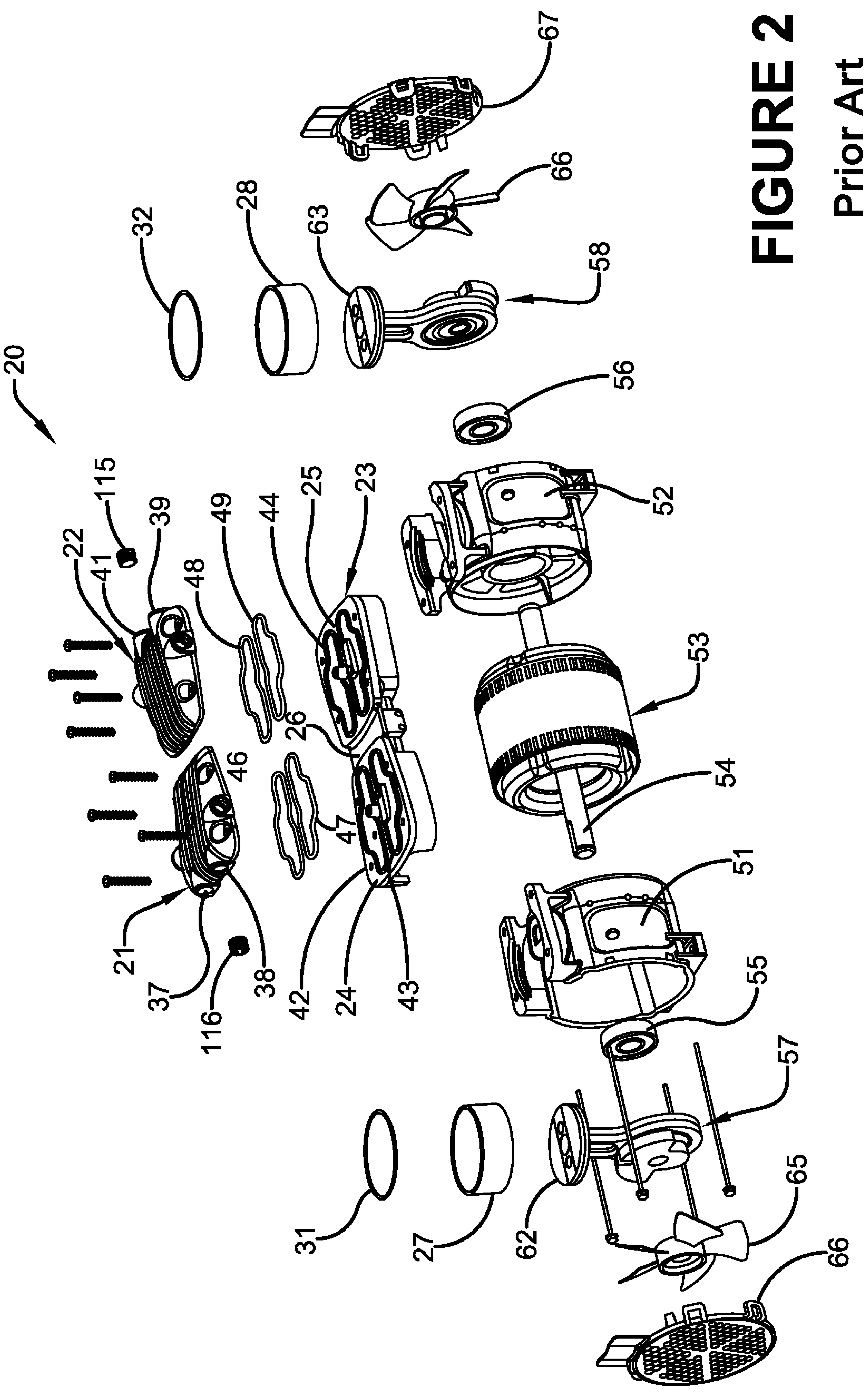

FIGURE 2
Prior Art

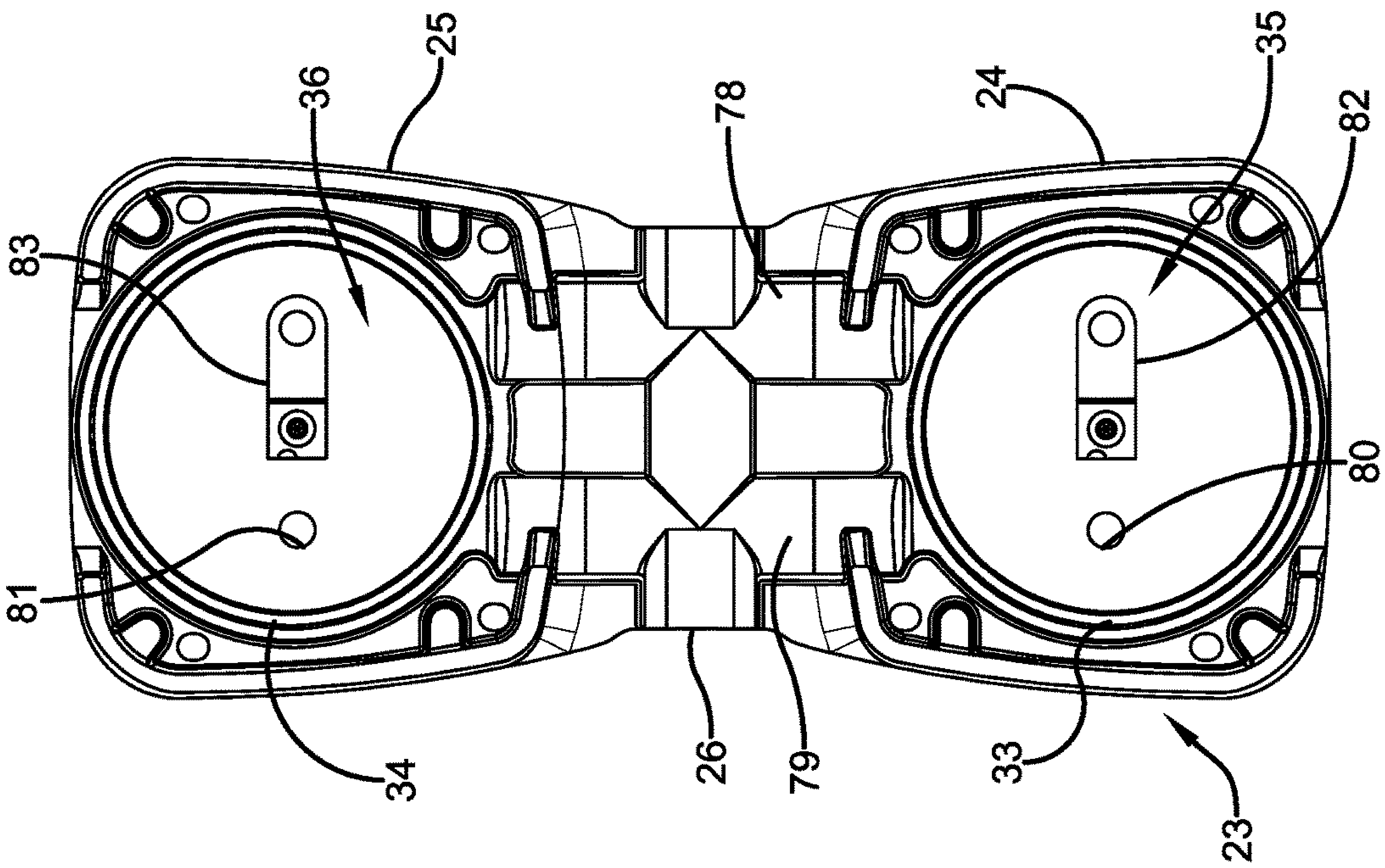

FIGURE 3B
Prior Art

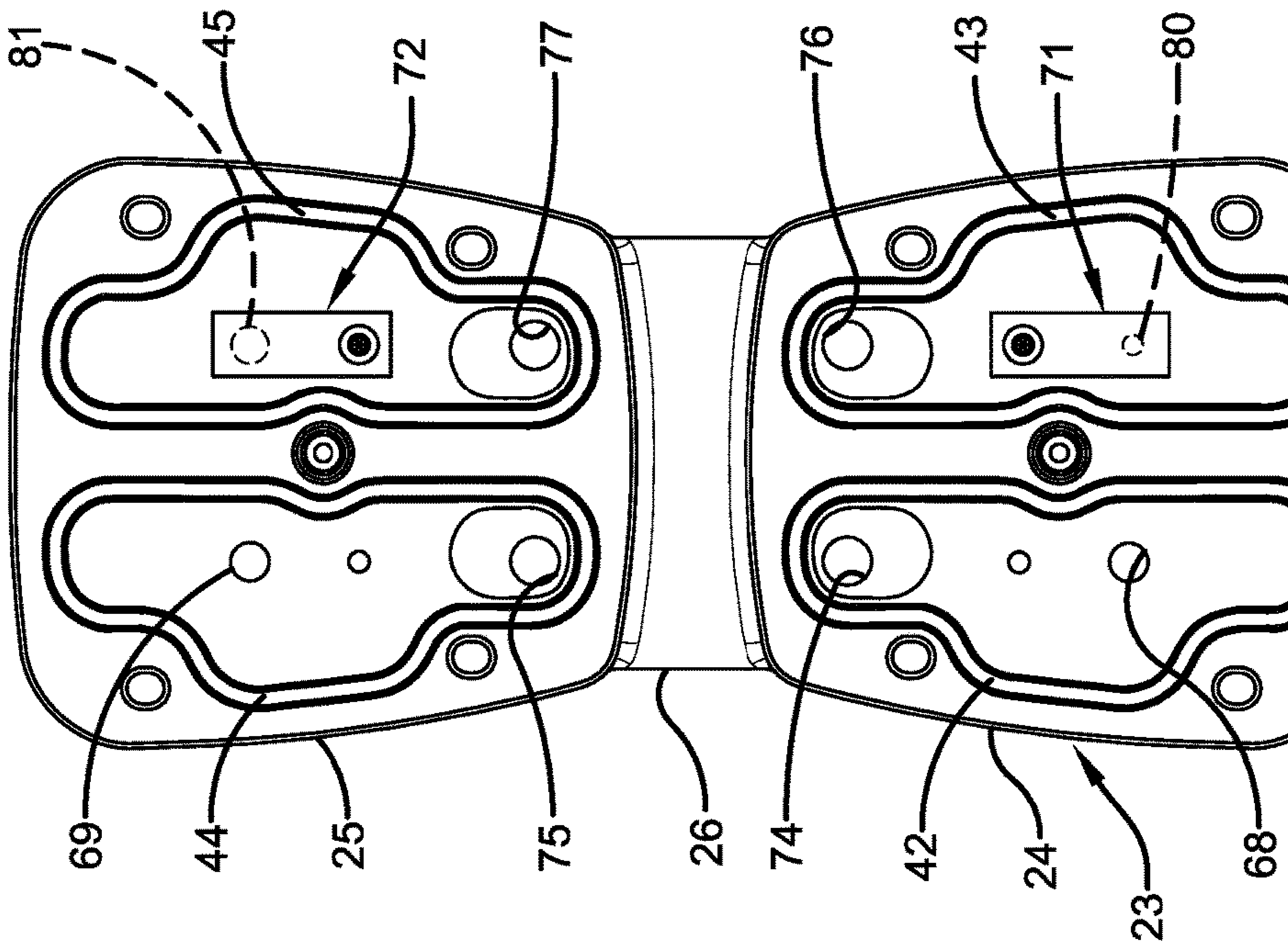

FIGURE 3A
Prior Art

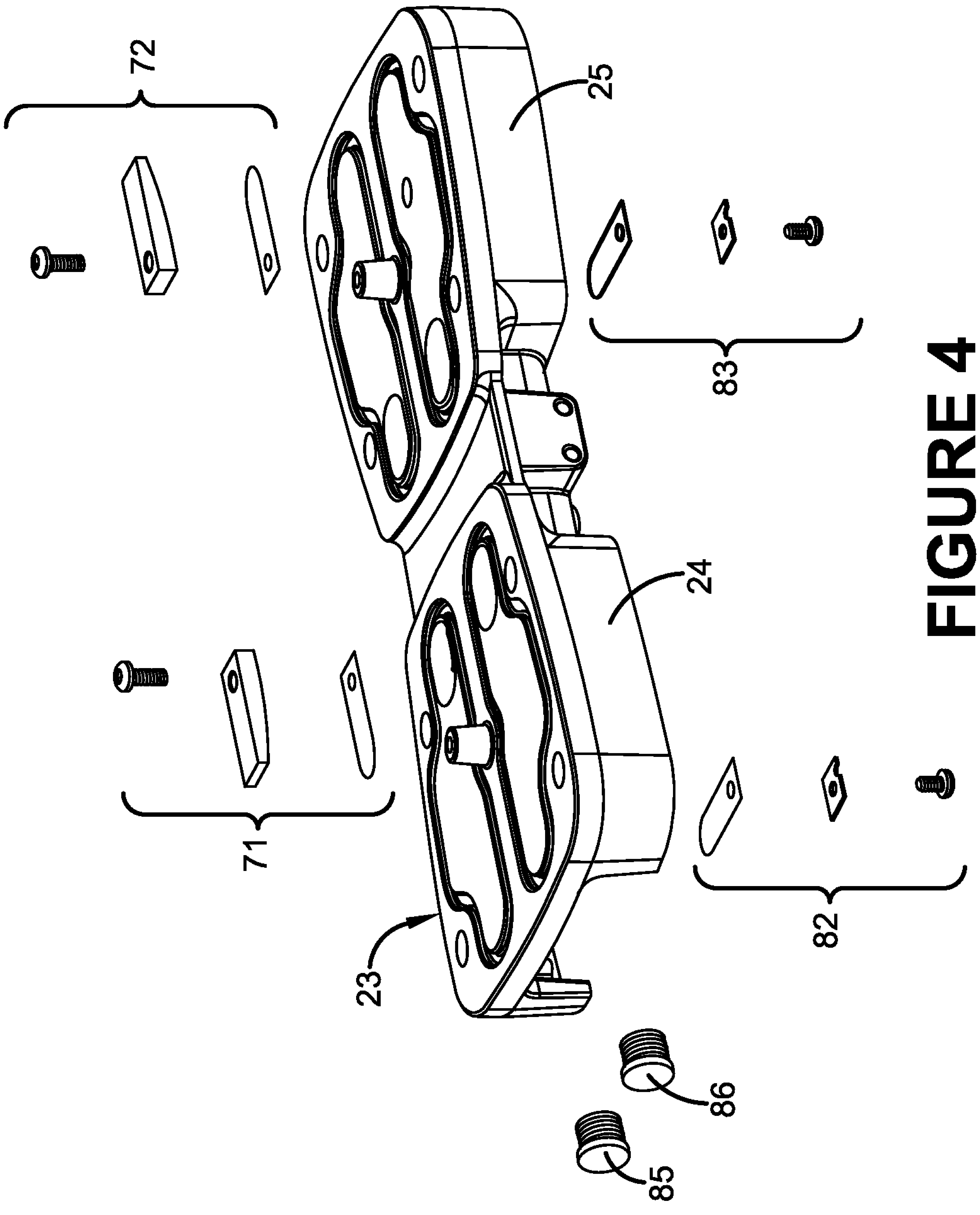

FIGURE 4
Prior Art

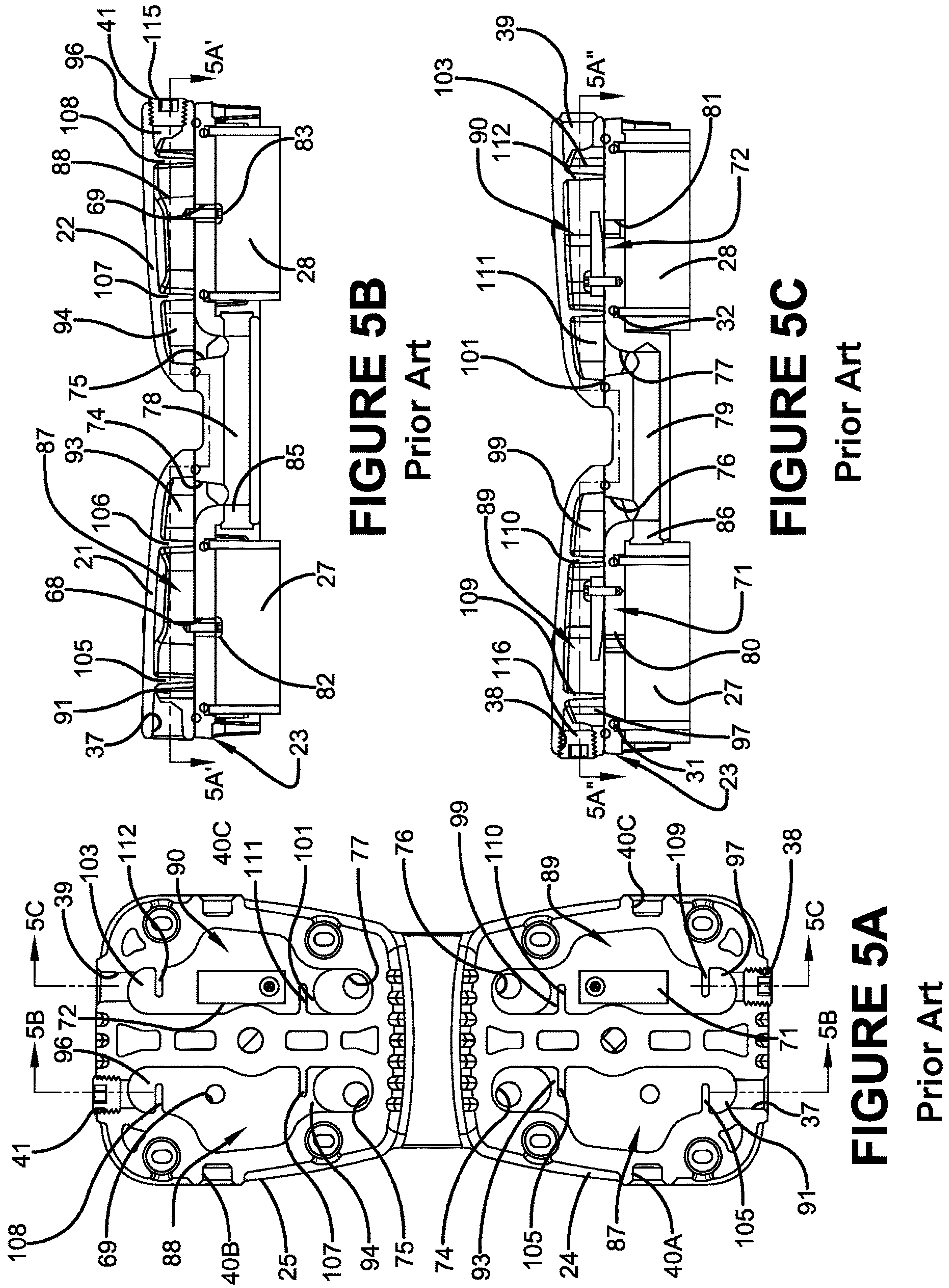

FIGURE 5A Prior Art

FIGURE 5B Prior Art

FIGURE 5C Prior Art

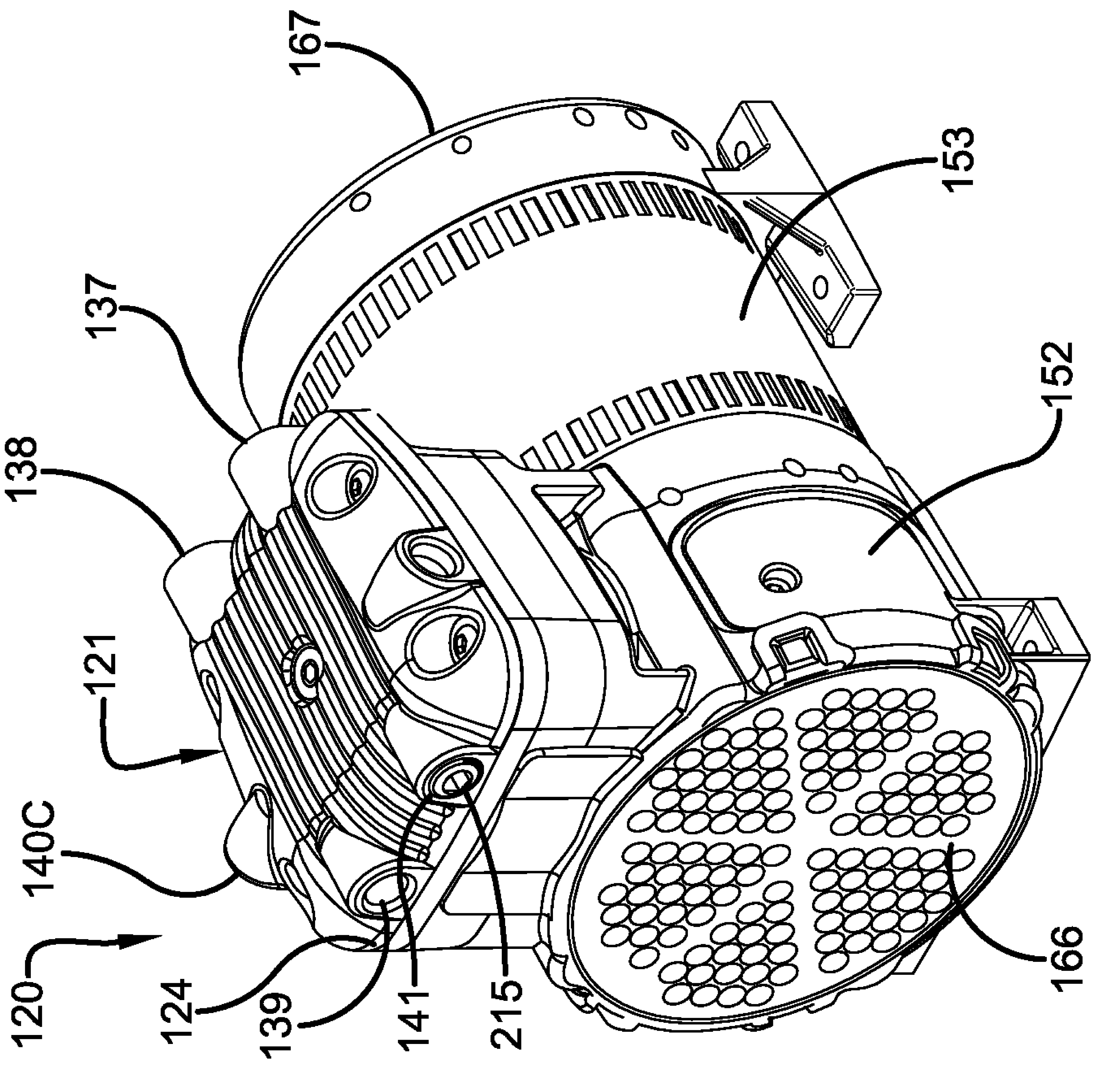

FIGURE 6A
Prior Art

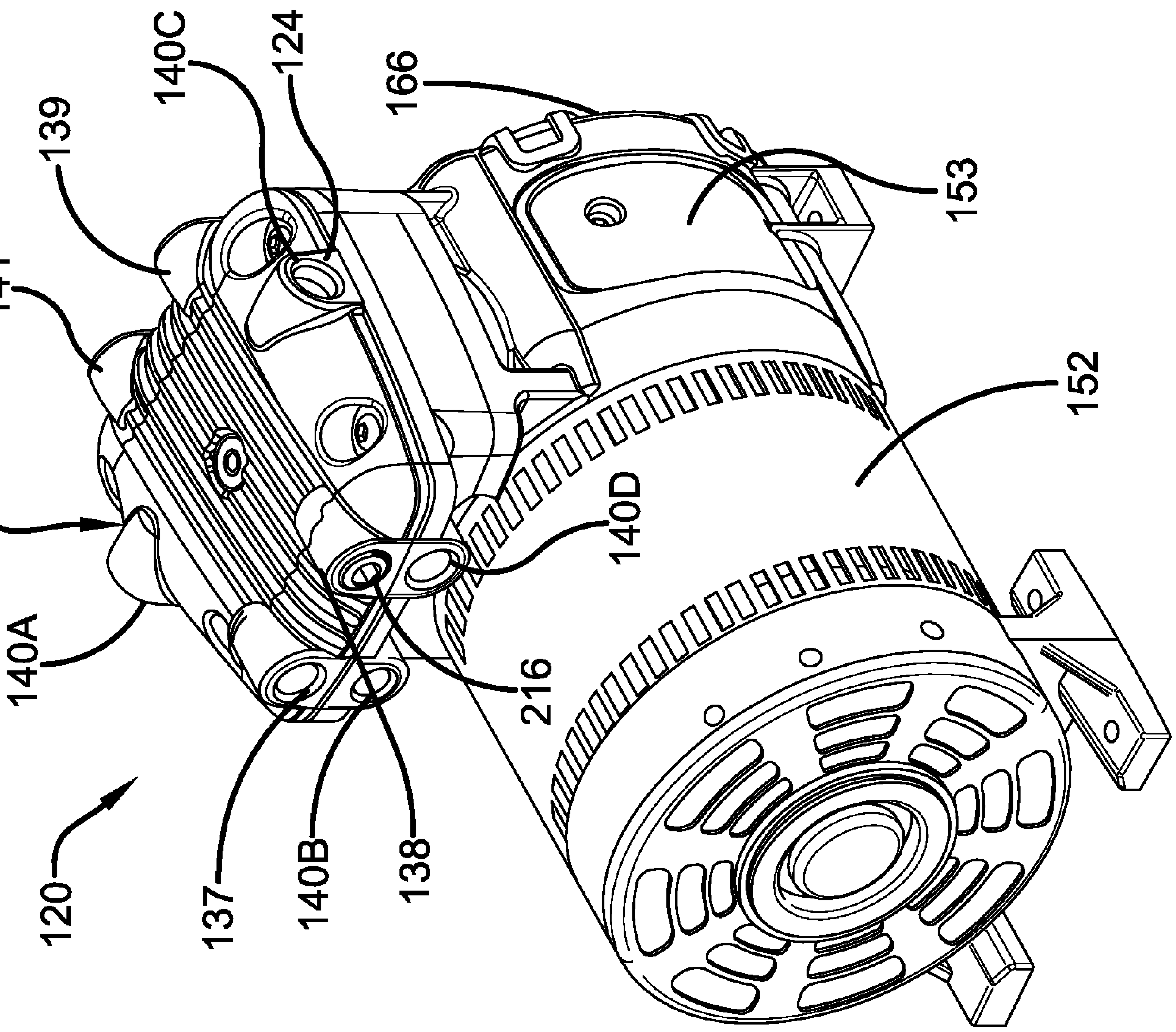

FIGURE 6B
Prior Art

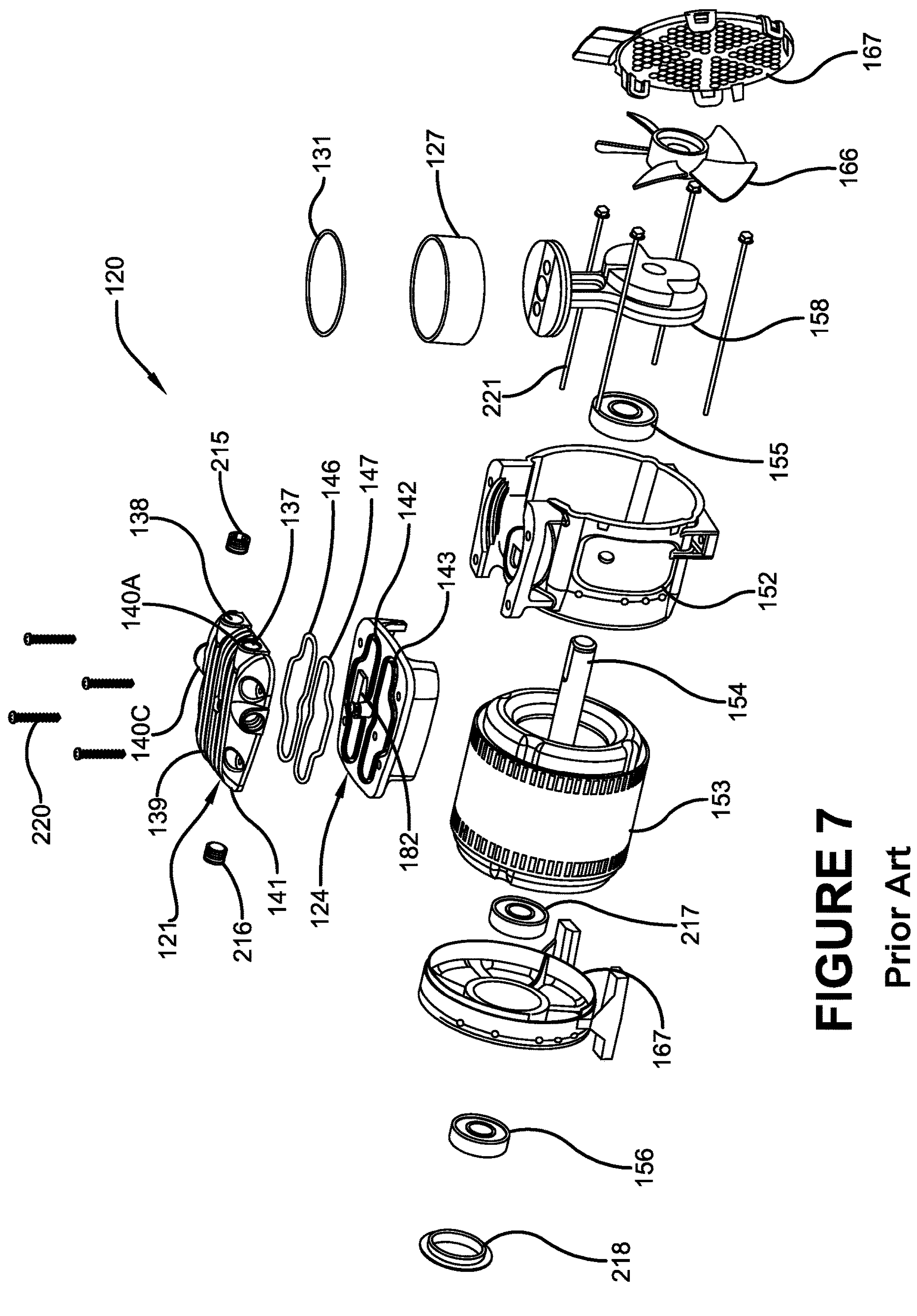

FIGURE 7
Prior Art

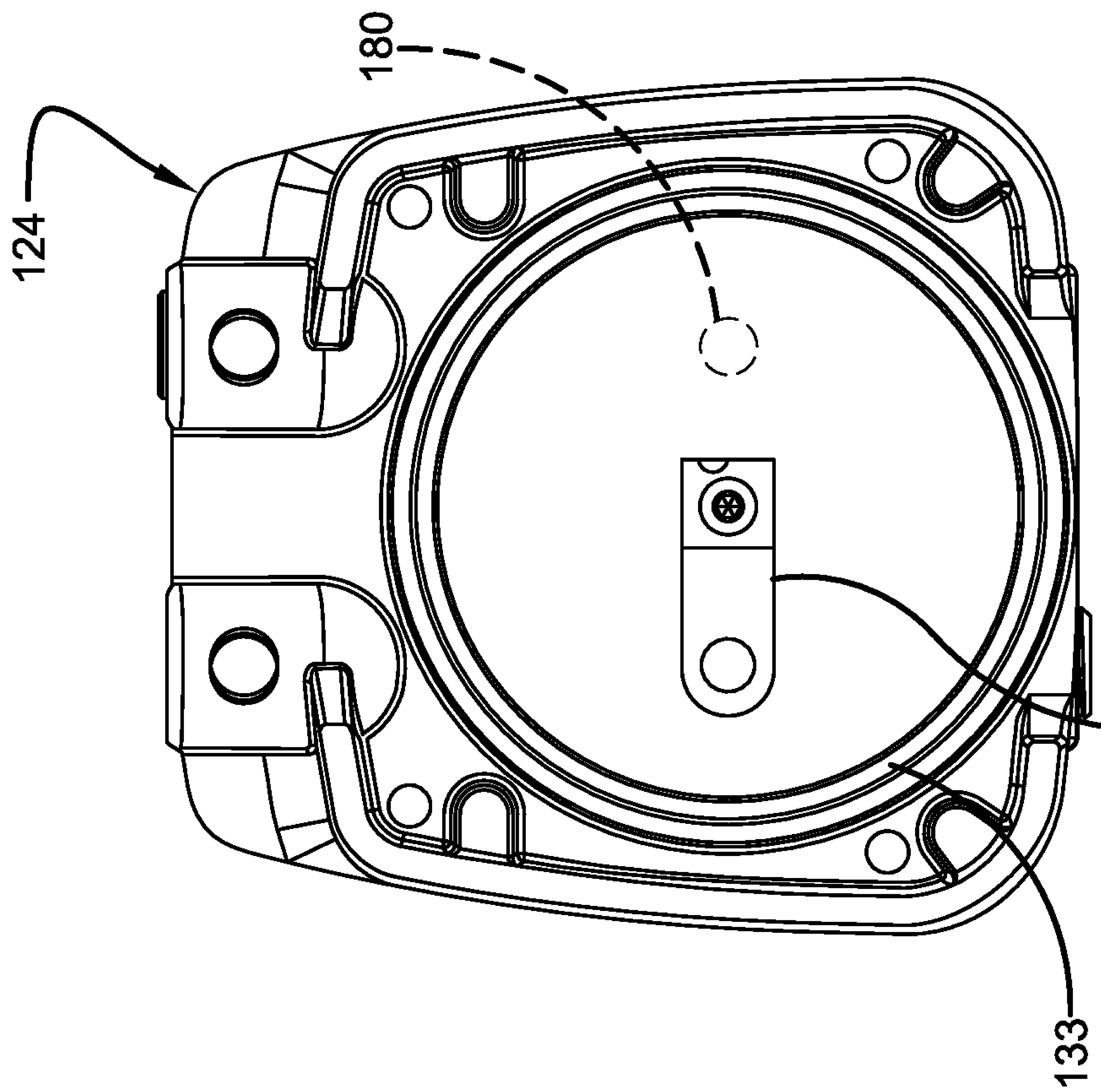

FIGURE 8B
Prior Art

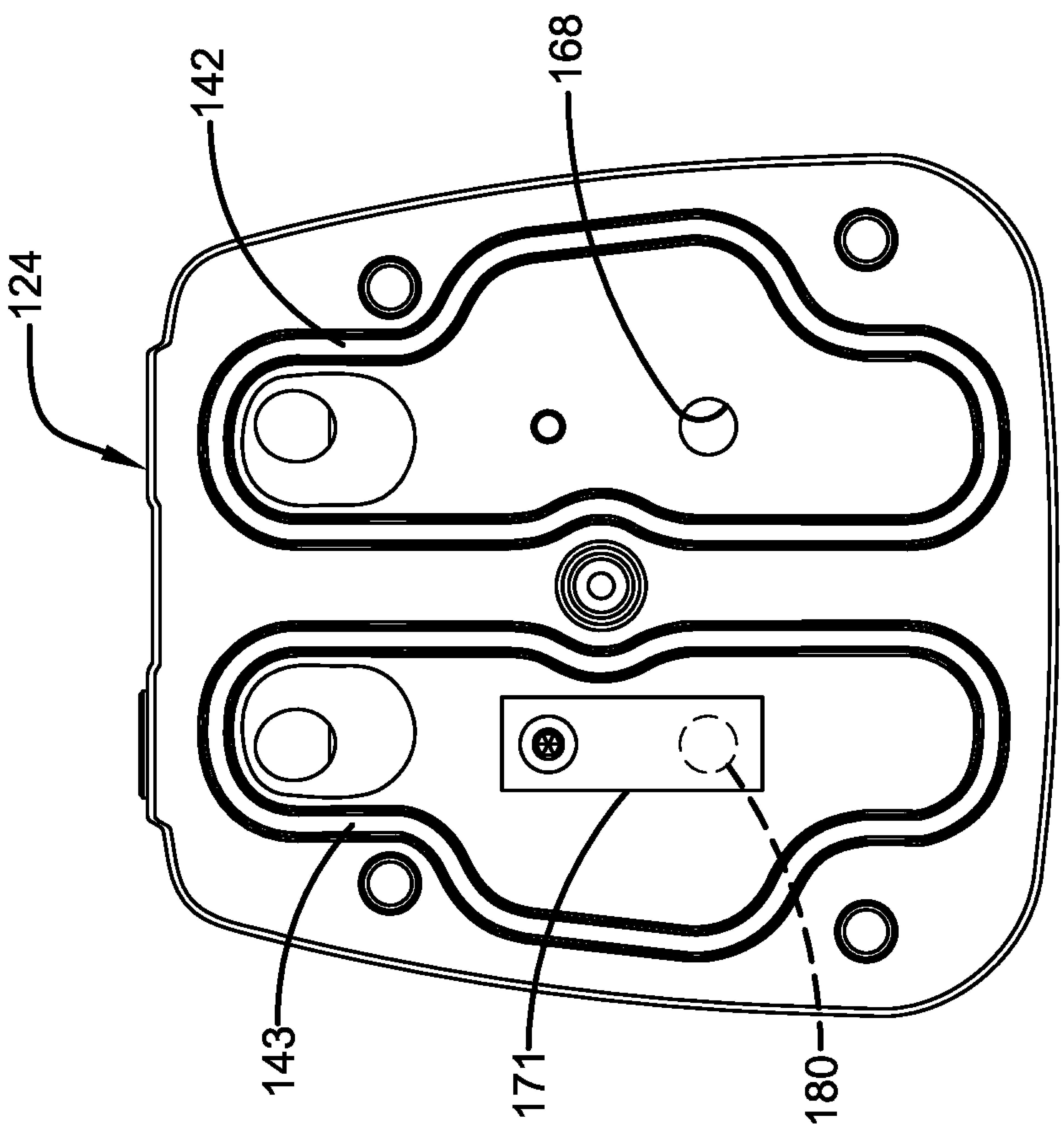

FIGURE 8A
Prior Art

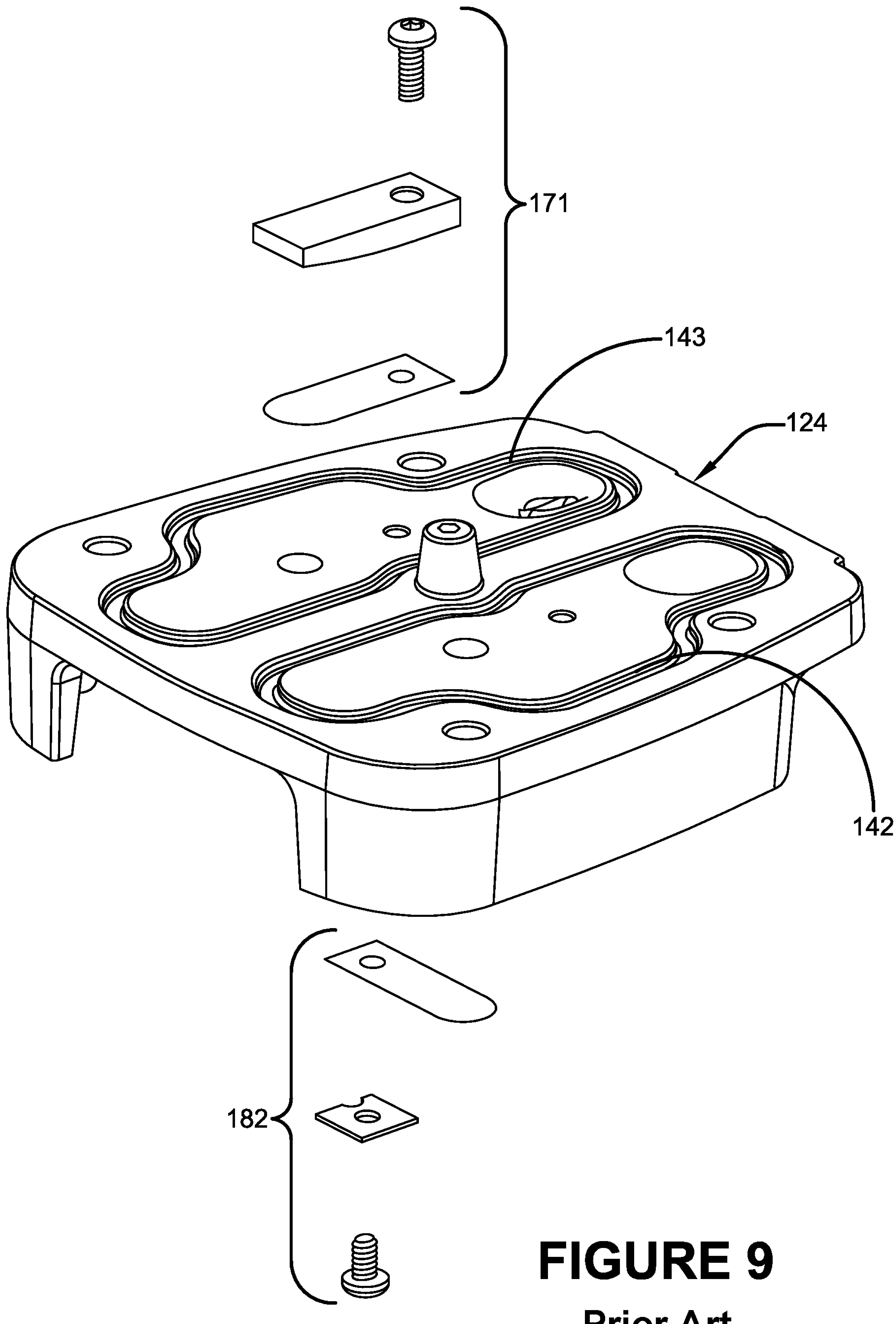

FIGURE 9
Prior Art

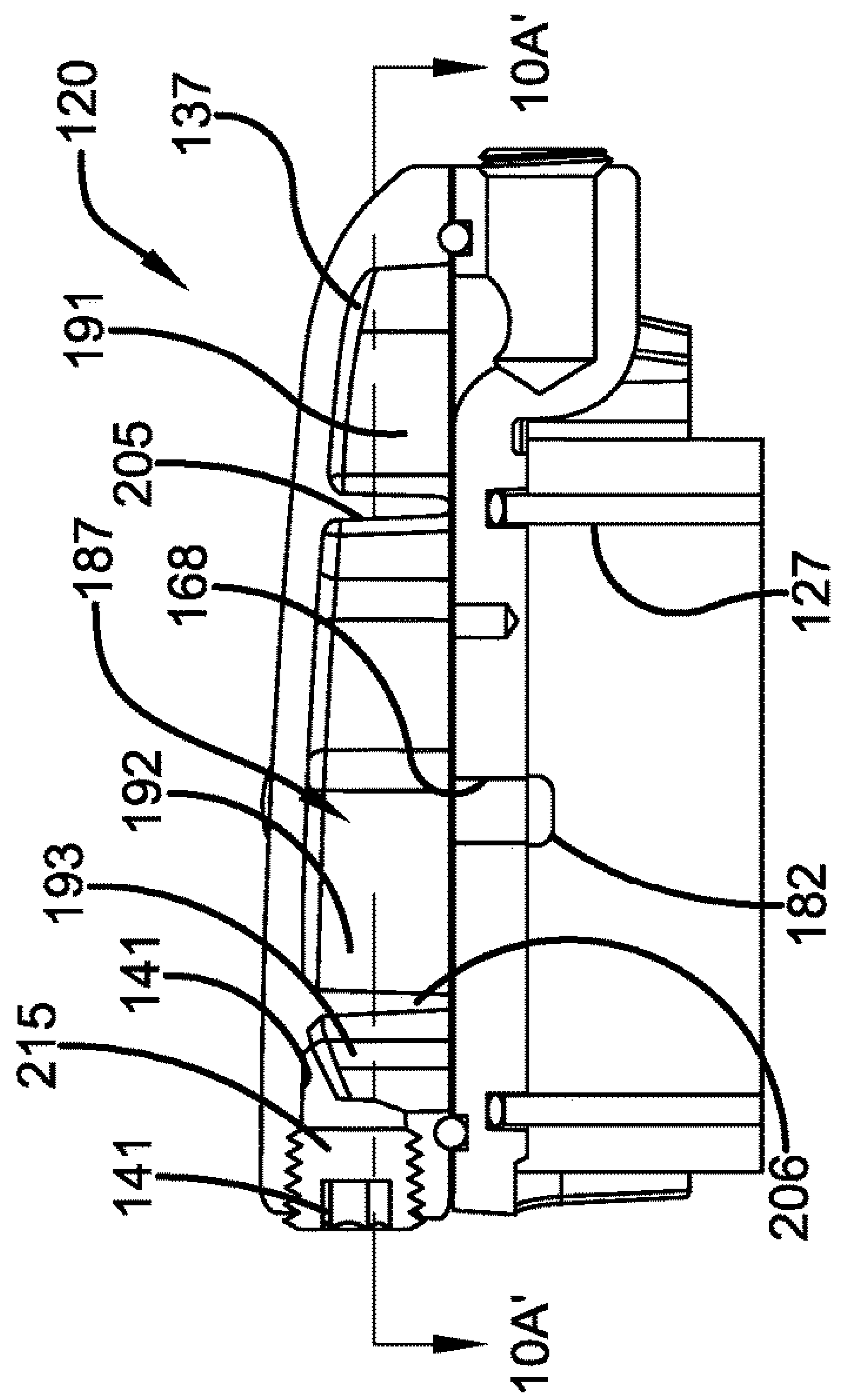

FIGURE 10B
Prior Art

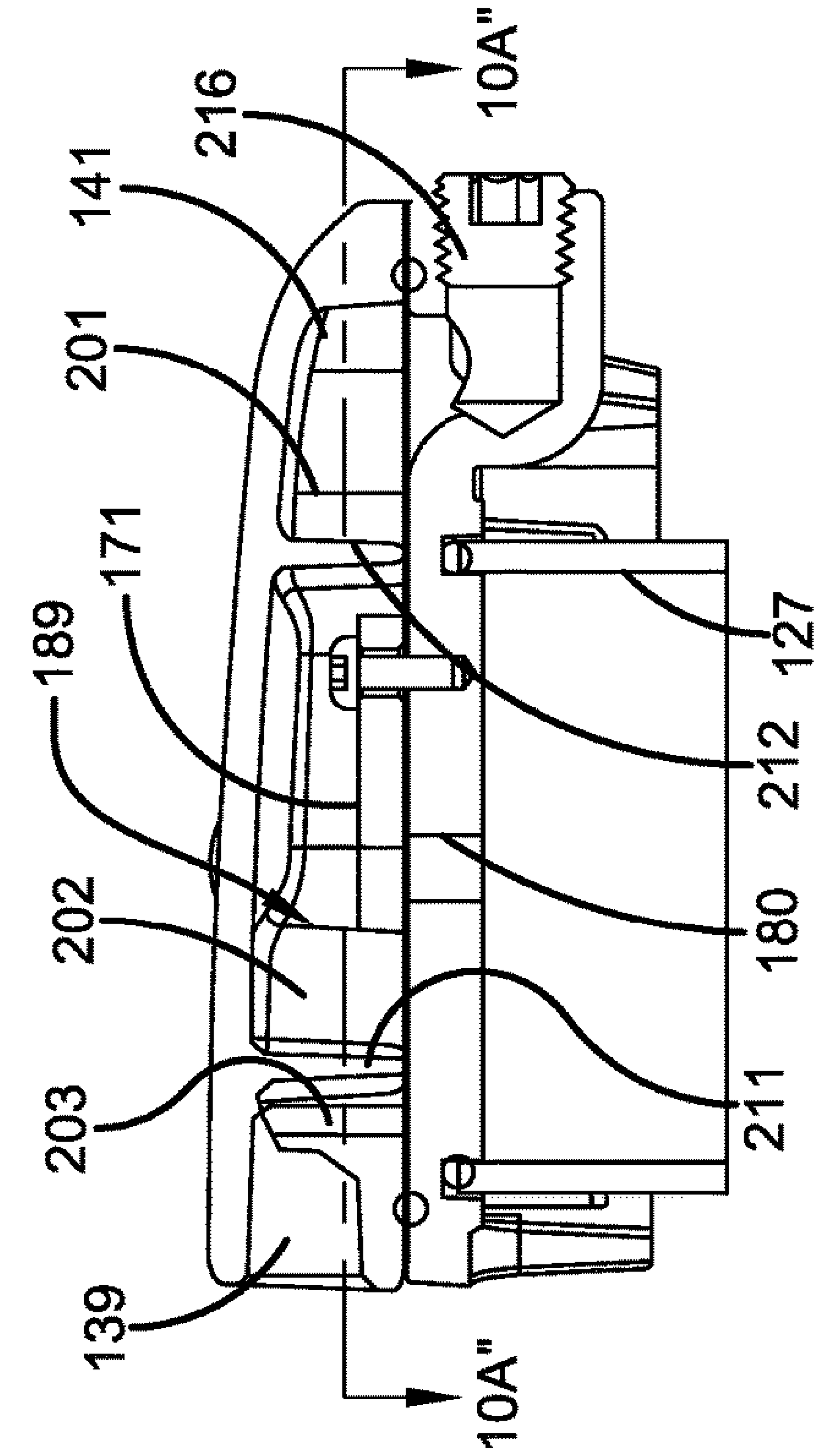

FIGURE 10C
Prior Art

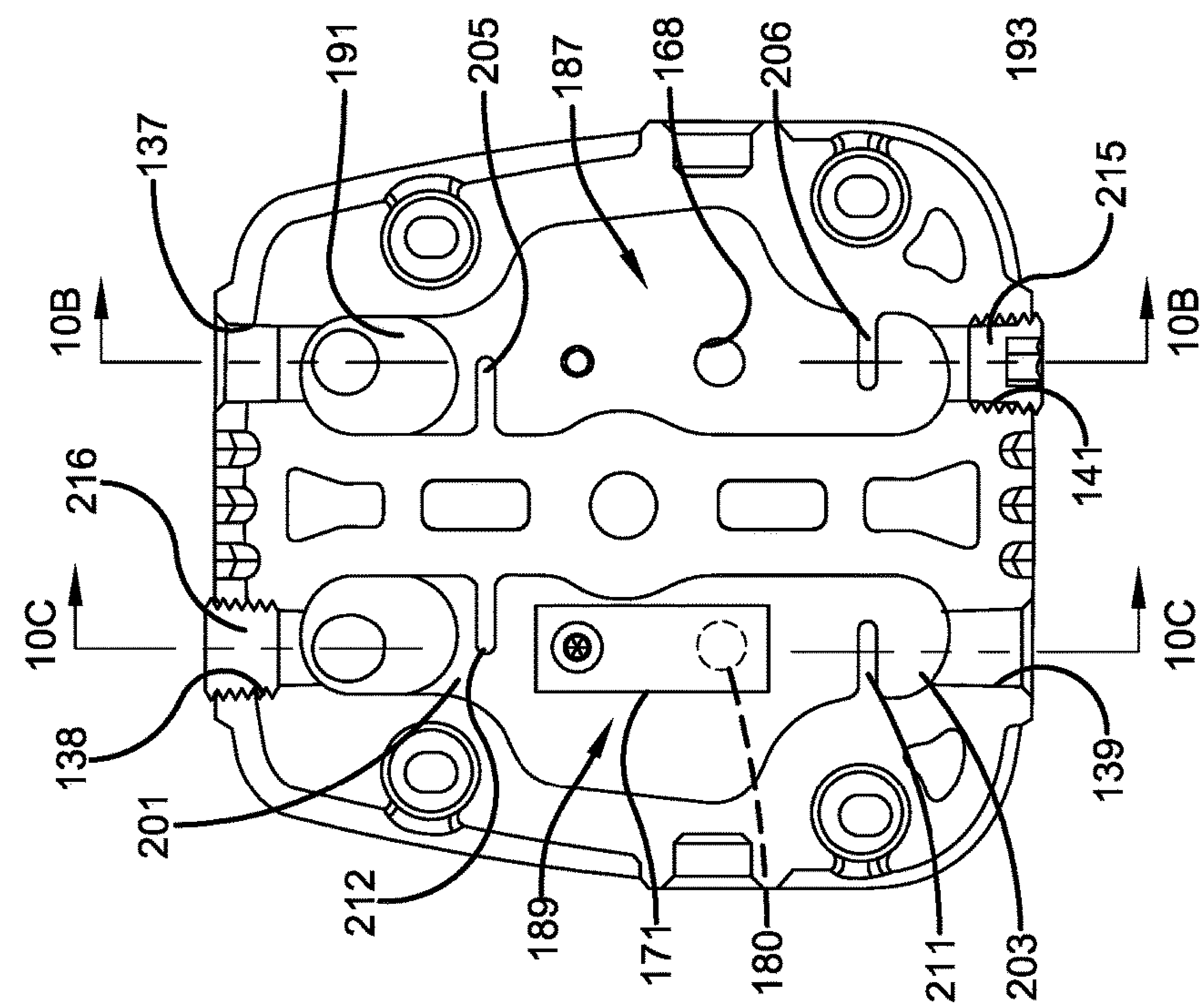

FIGURE 10A
Prior Art

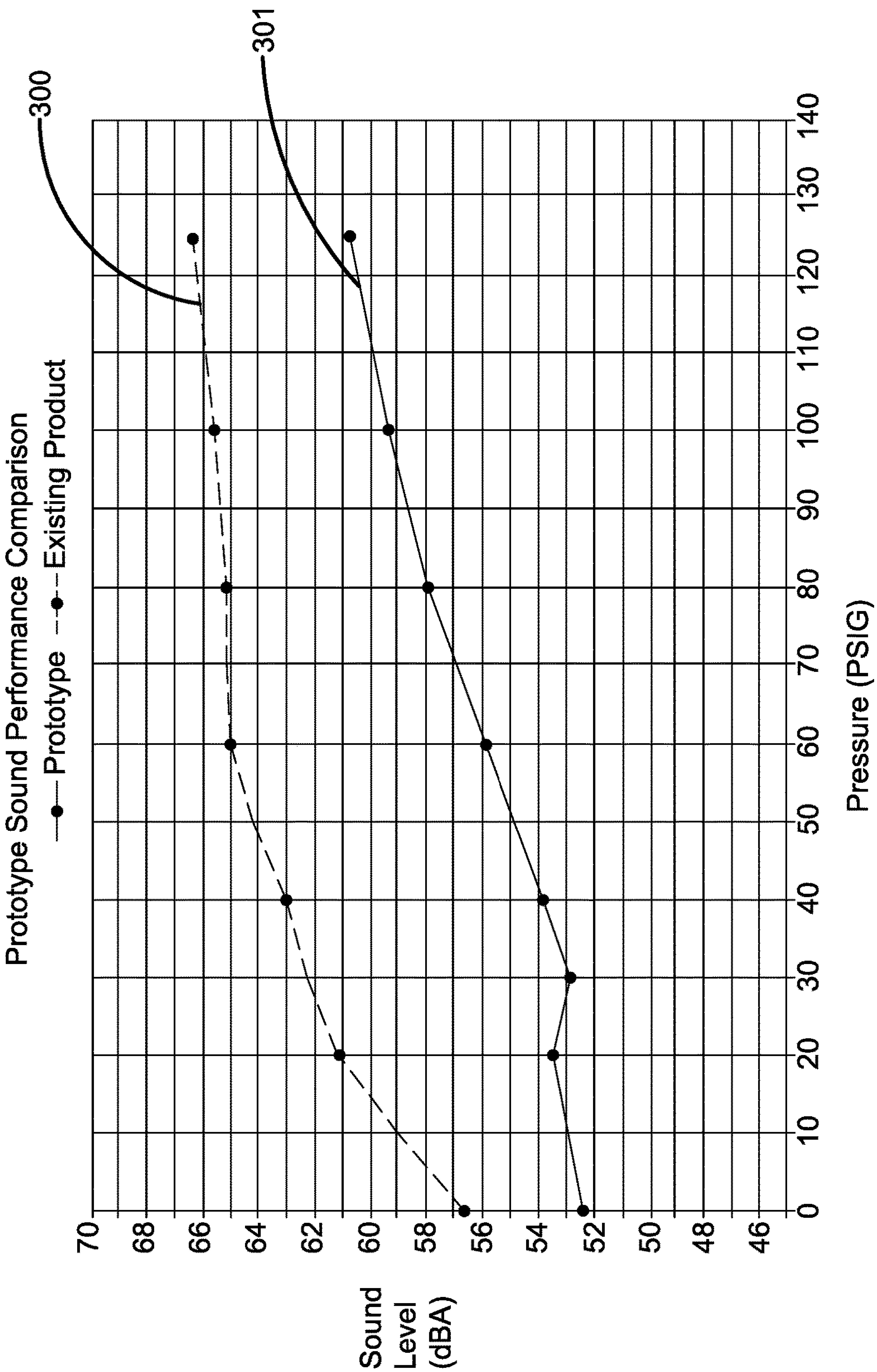

FIGURE 11
Prior Art

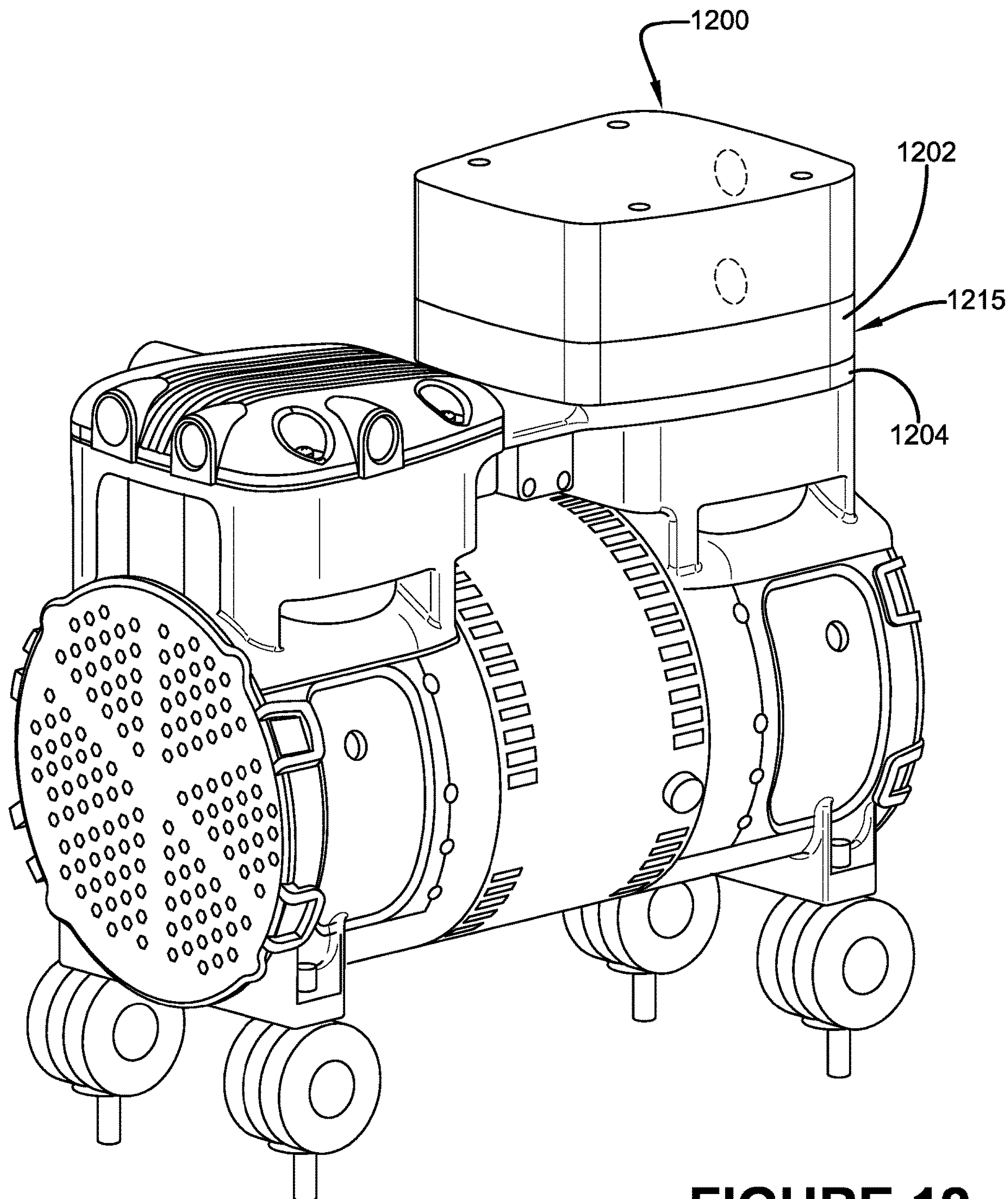

FIGURE 12

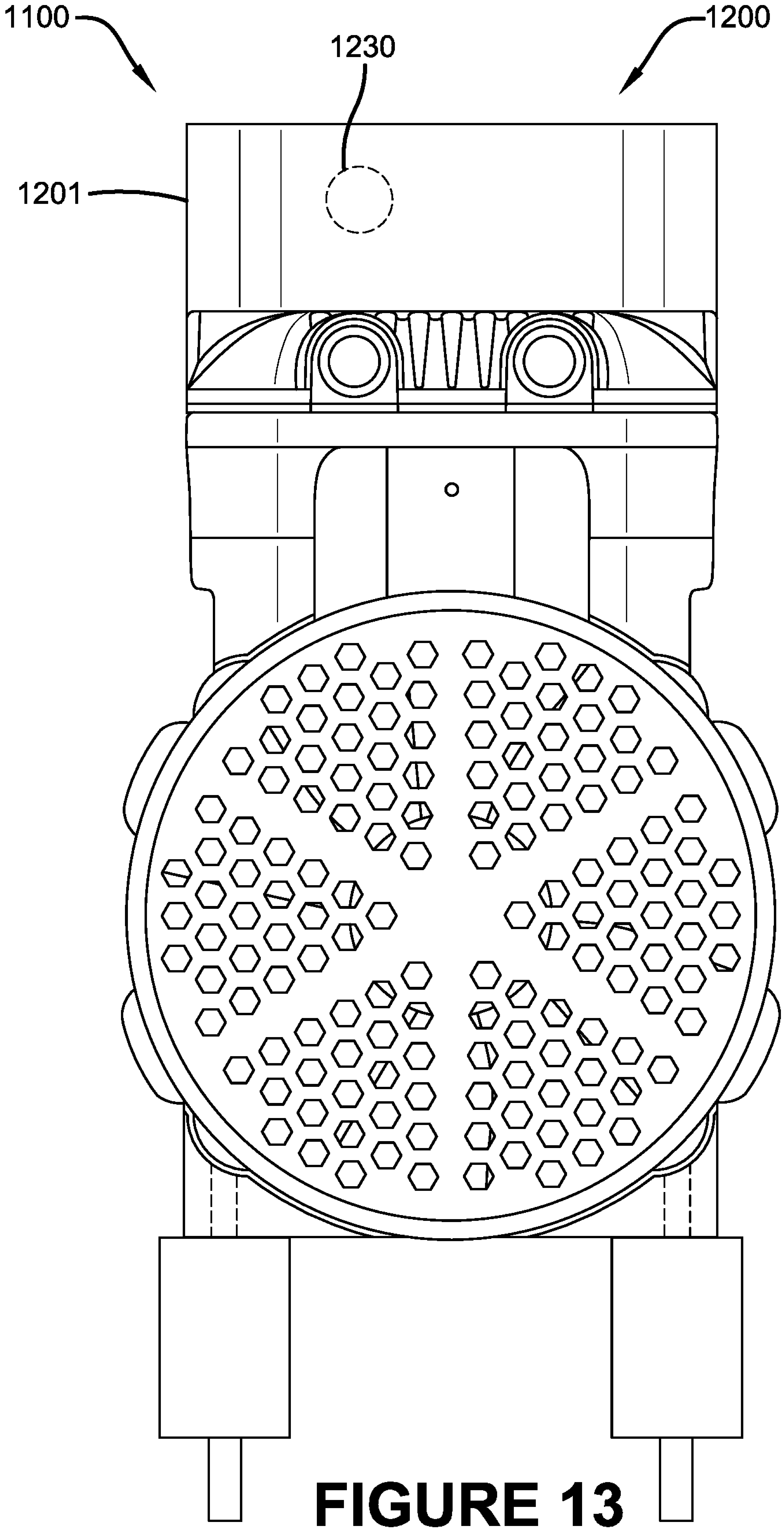

FIGURE 13

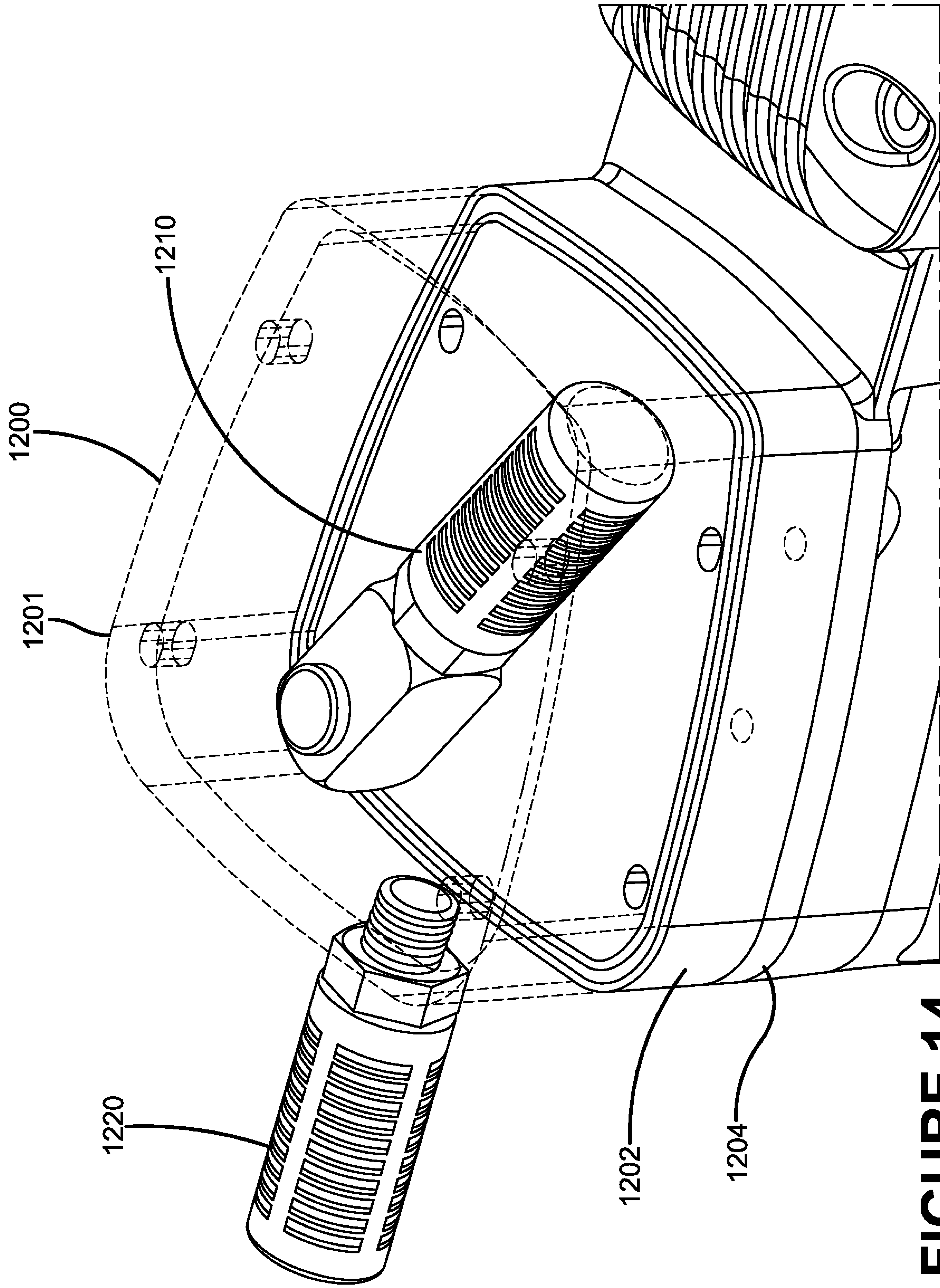

FIGURE 14

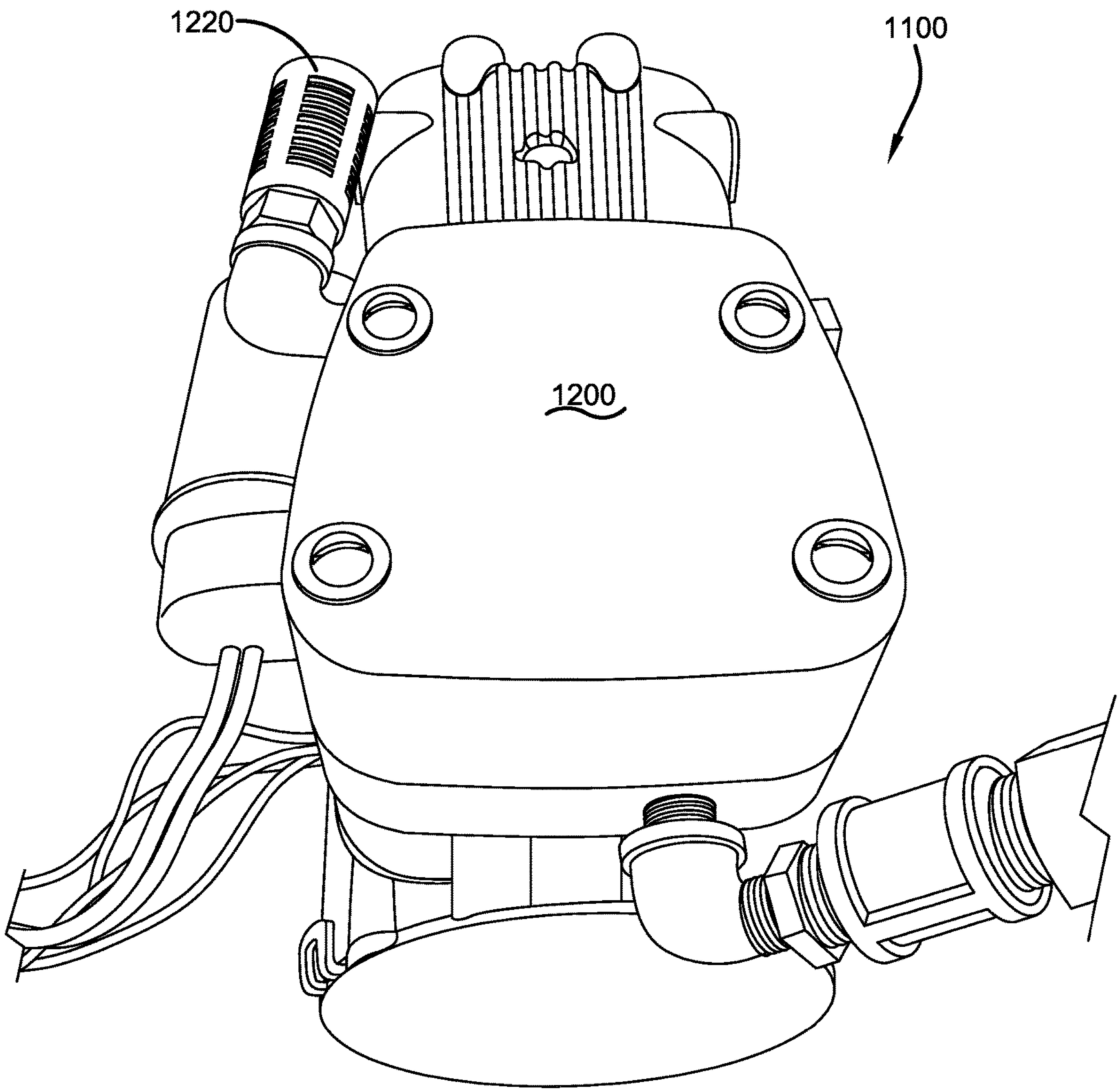

FIGURE 15A

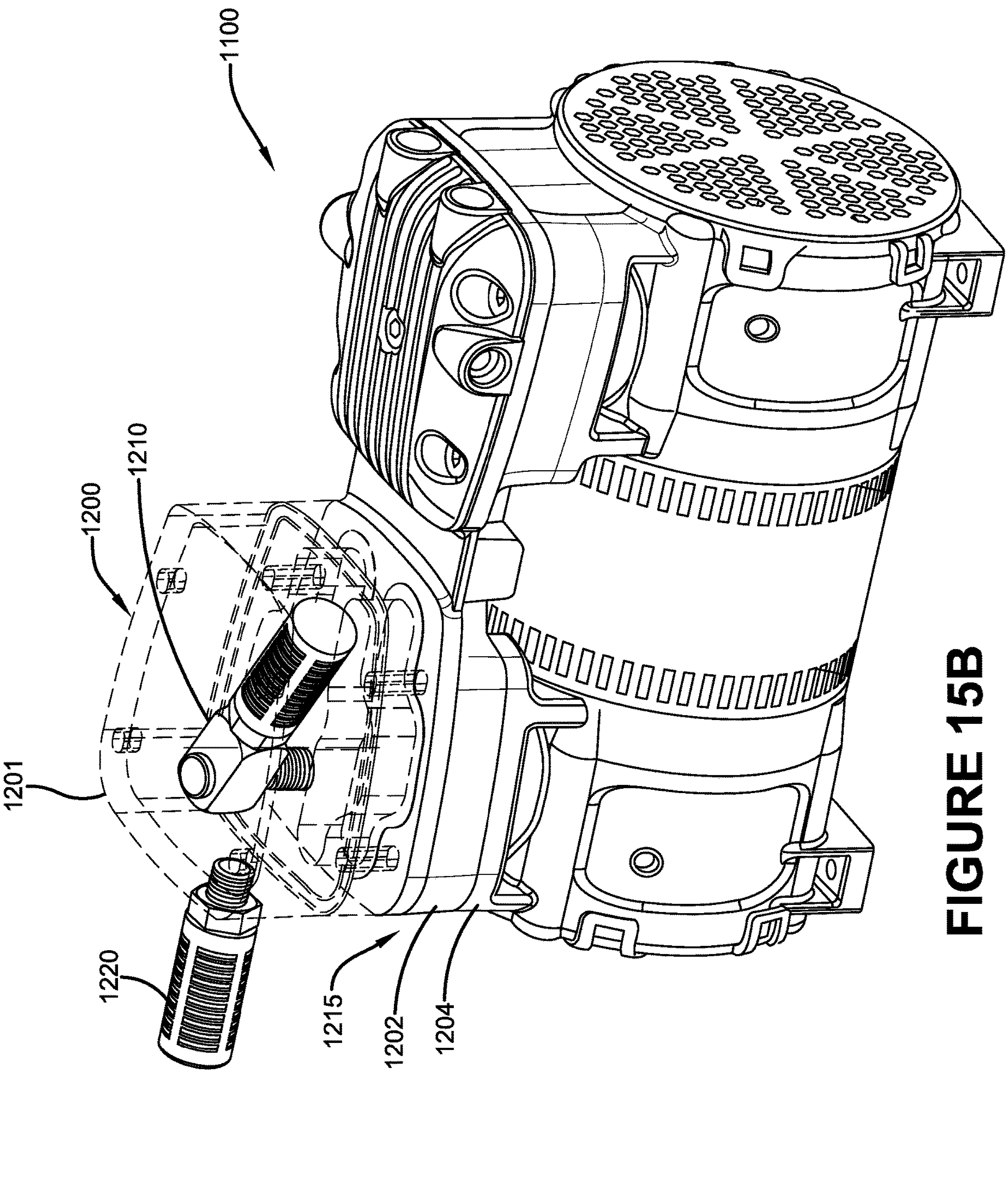

FIGURE 15B

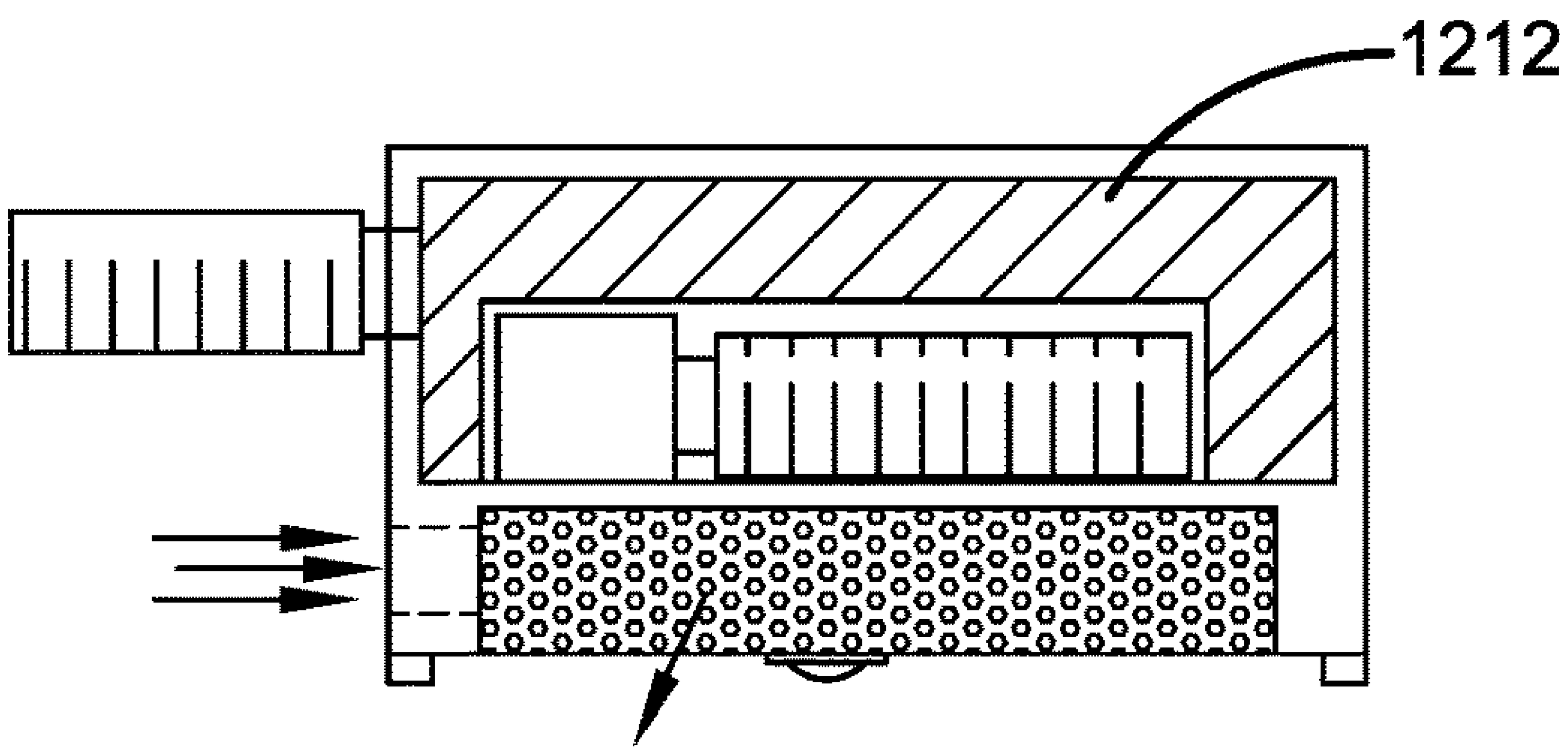

FIGURE 16B

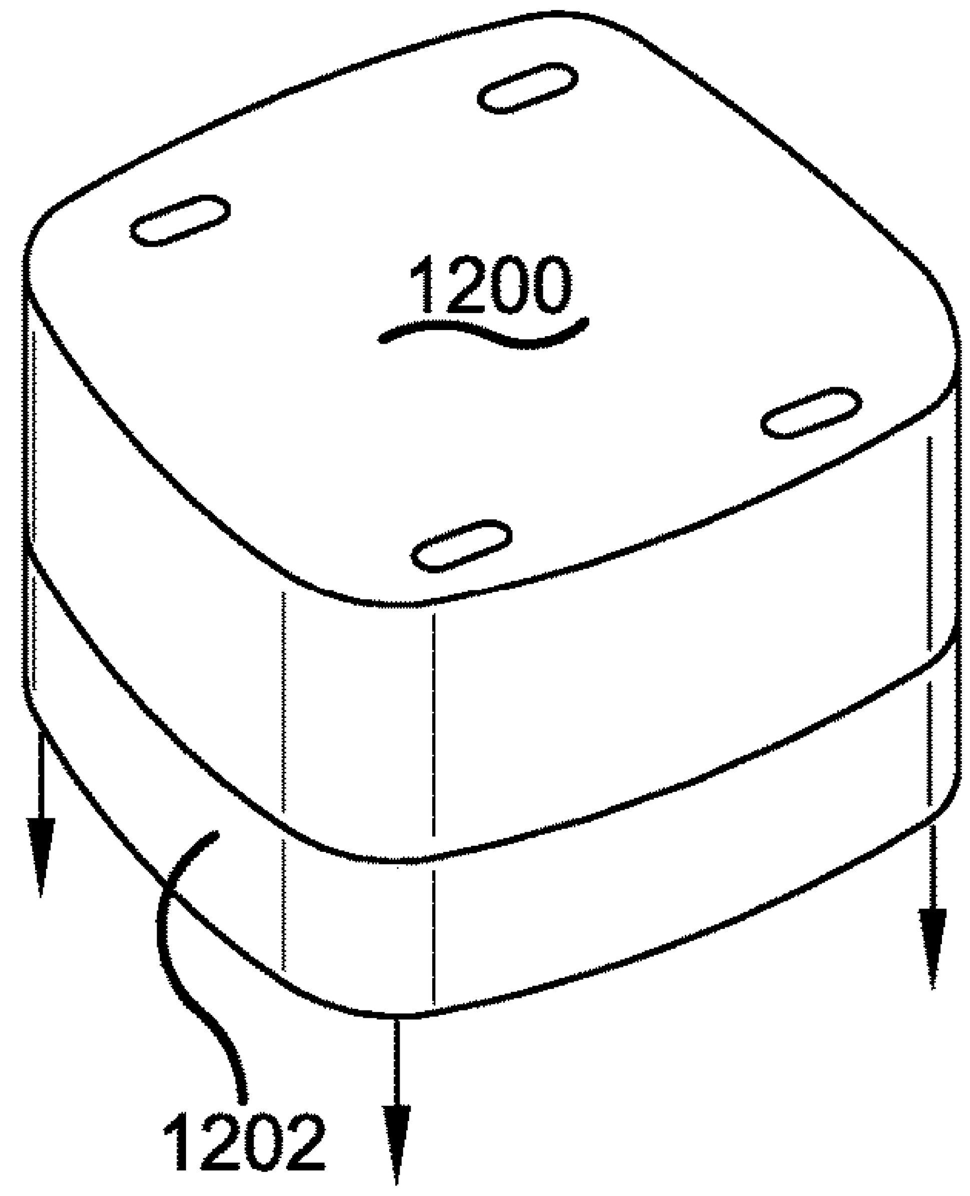

FIGURE 16A

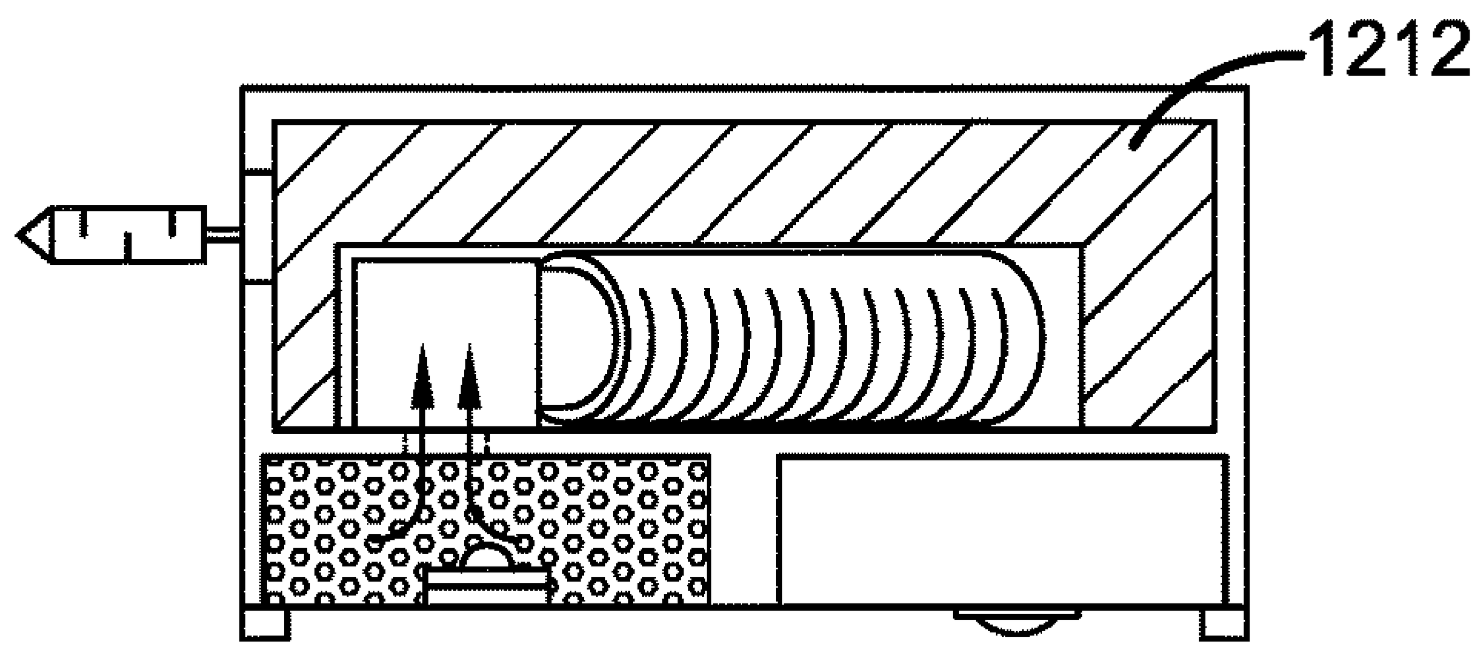

FIGURE 16C

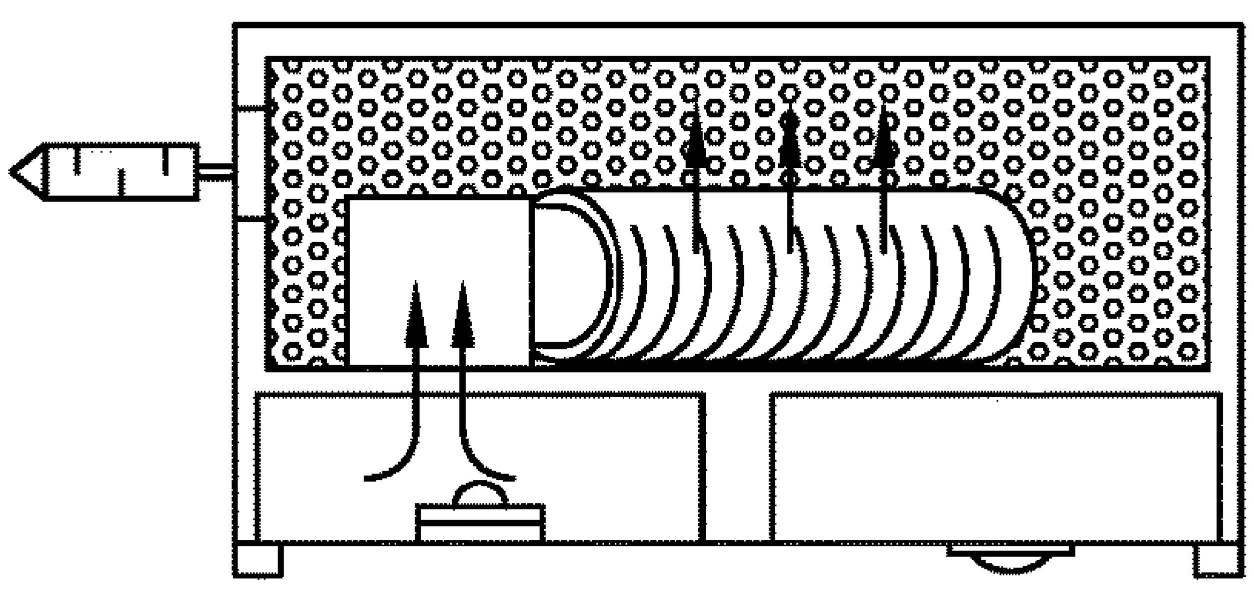

FIGURE 16D

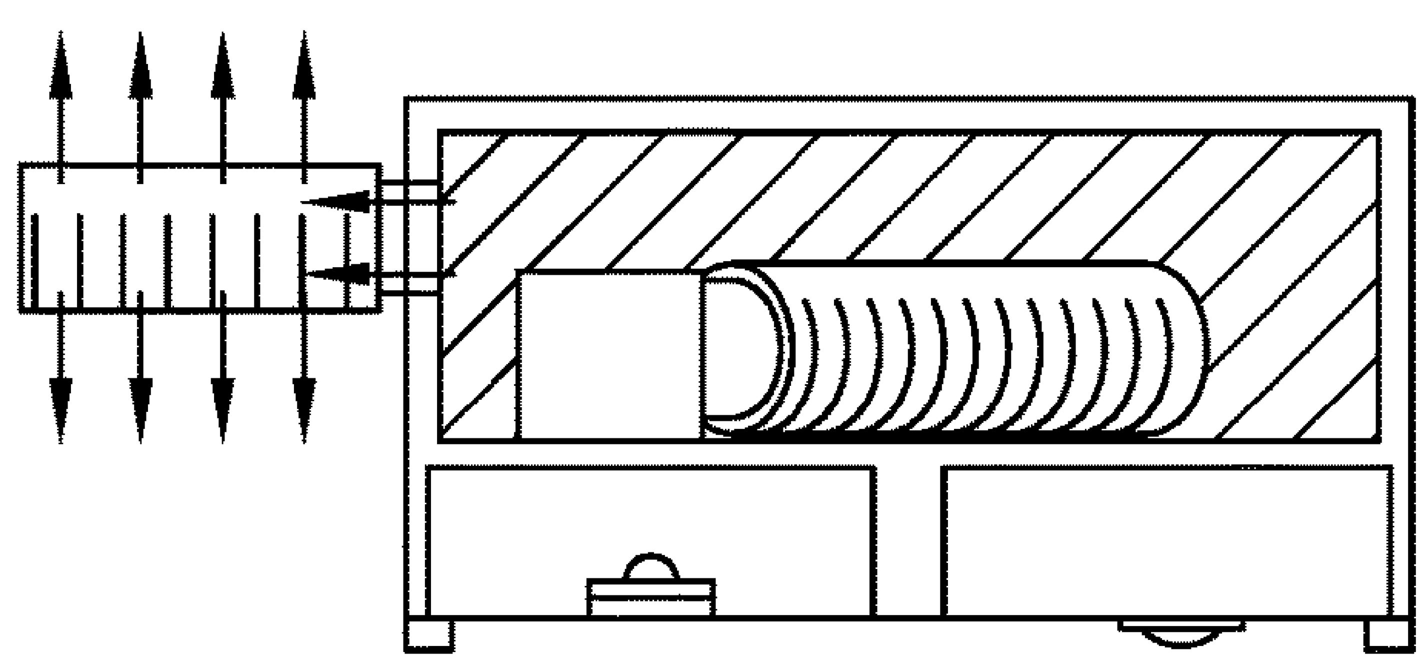

FIGURE 16E

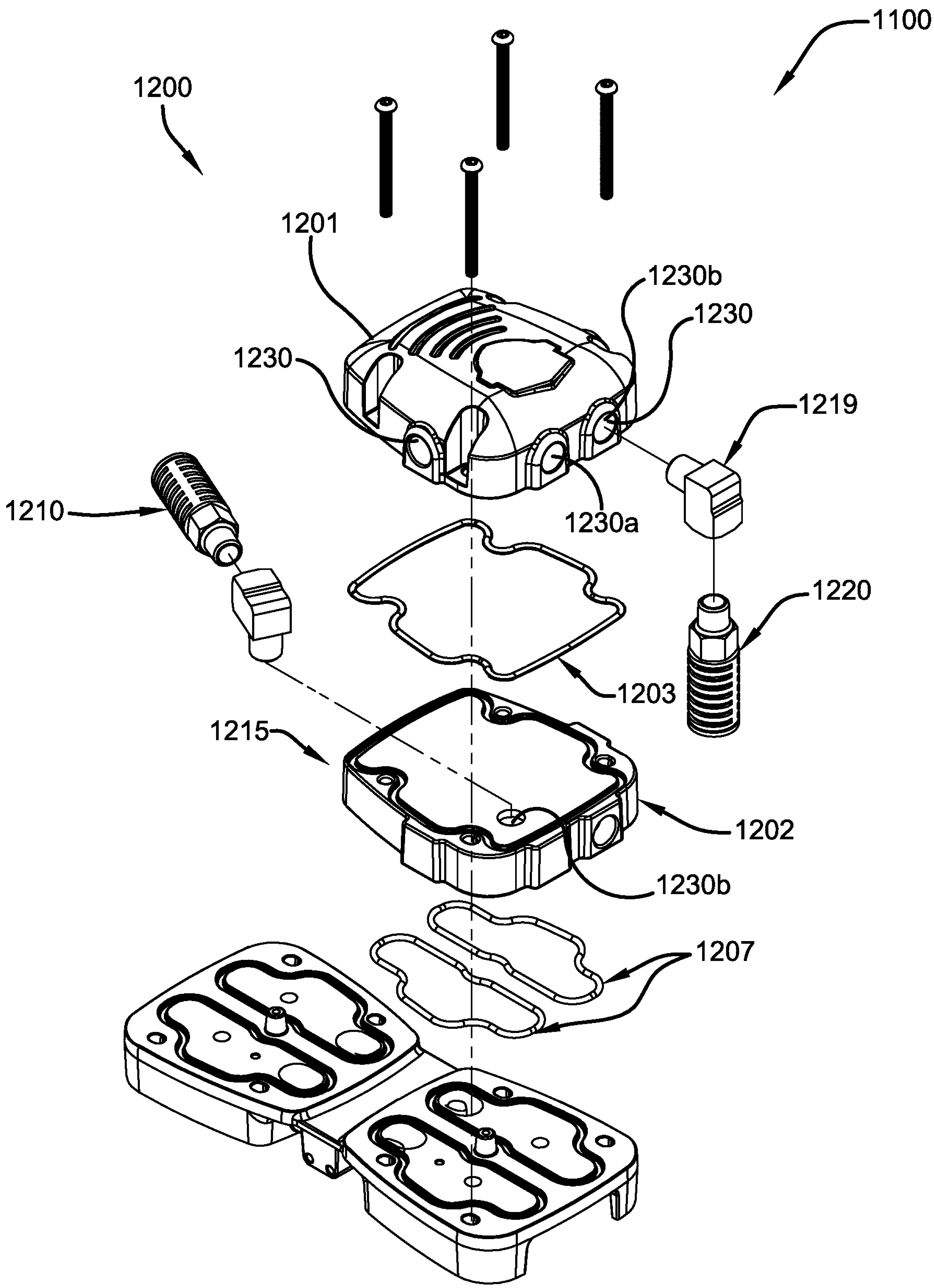
1100
1200
1201
1230b
1230
1230
1219
1210
1230a
1220
1203
1215
1202
1230b
1207

FIGURE 17

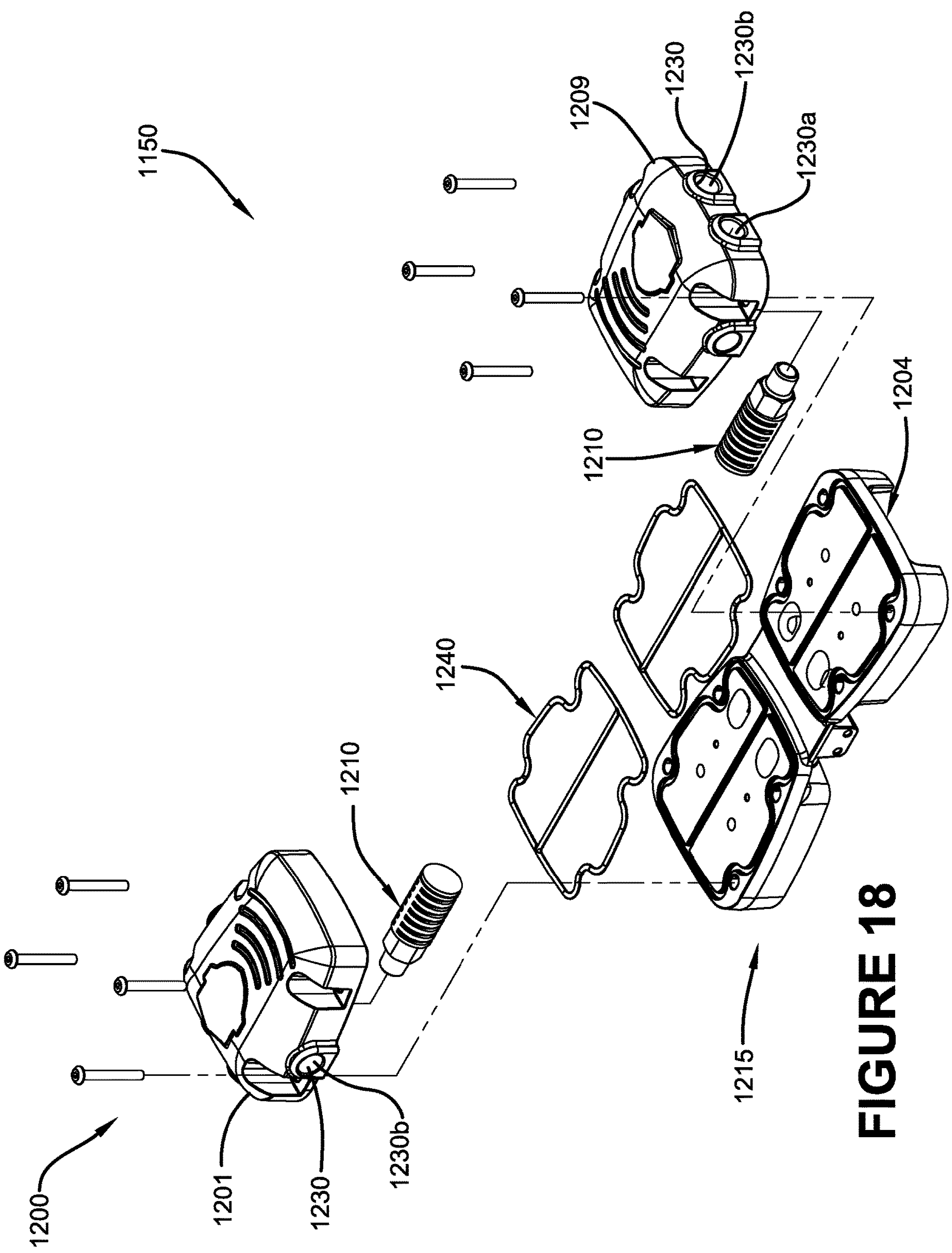
1150
1209
1230
1230b
1230a
1210
1204
1240
1210
1215
1200
1201
1230
1230b

FIGURE 18

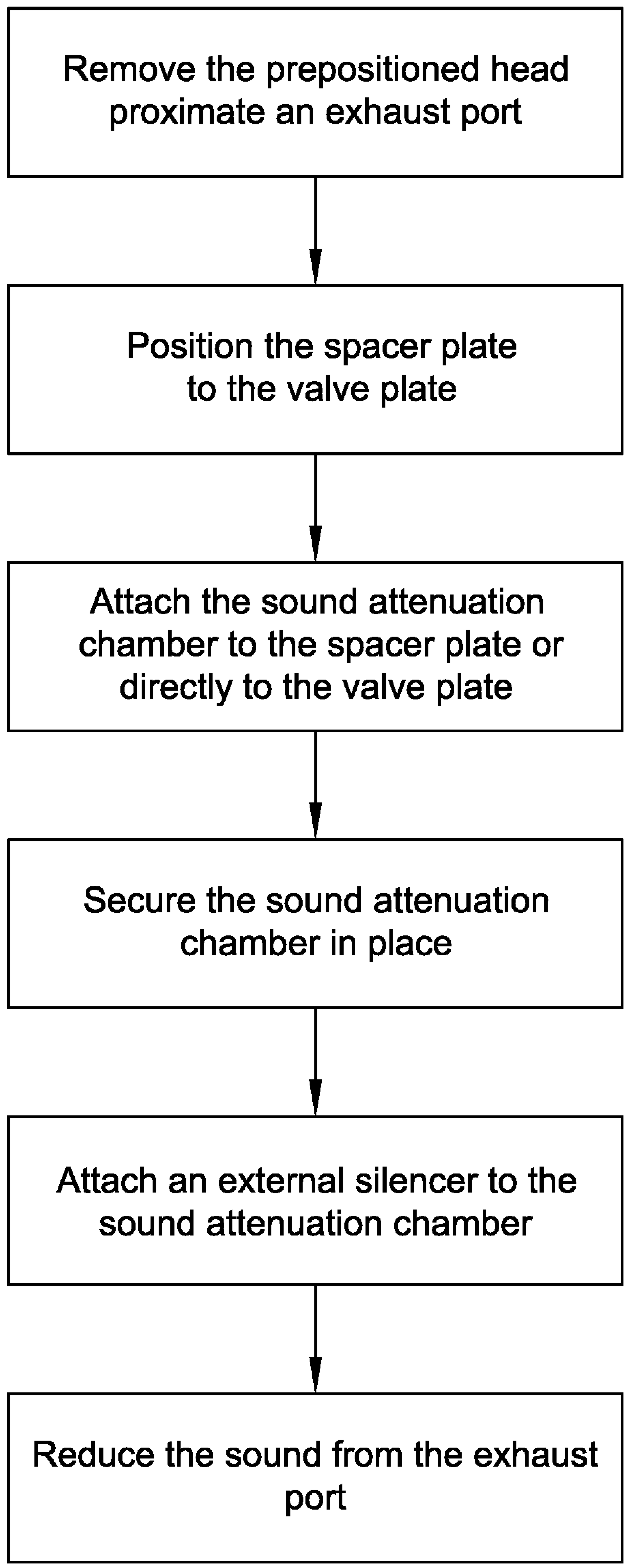
Remove the prepositioned head proximate an exhaust port
Position the spacer plate to the valve plate
Attach the sound attenuation chamber to the spacer plate or directly to the valve plate
Secure the sound attenuation chamber in place
Attach an external silencer to the sound attenuation chamber
Reduce the sound from the exhaust port

FIGURE 19A

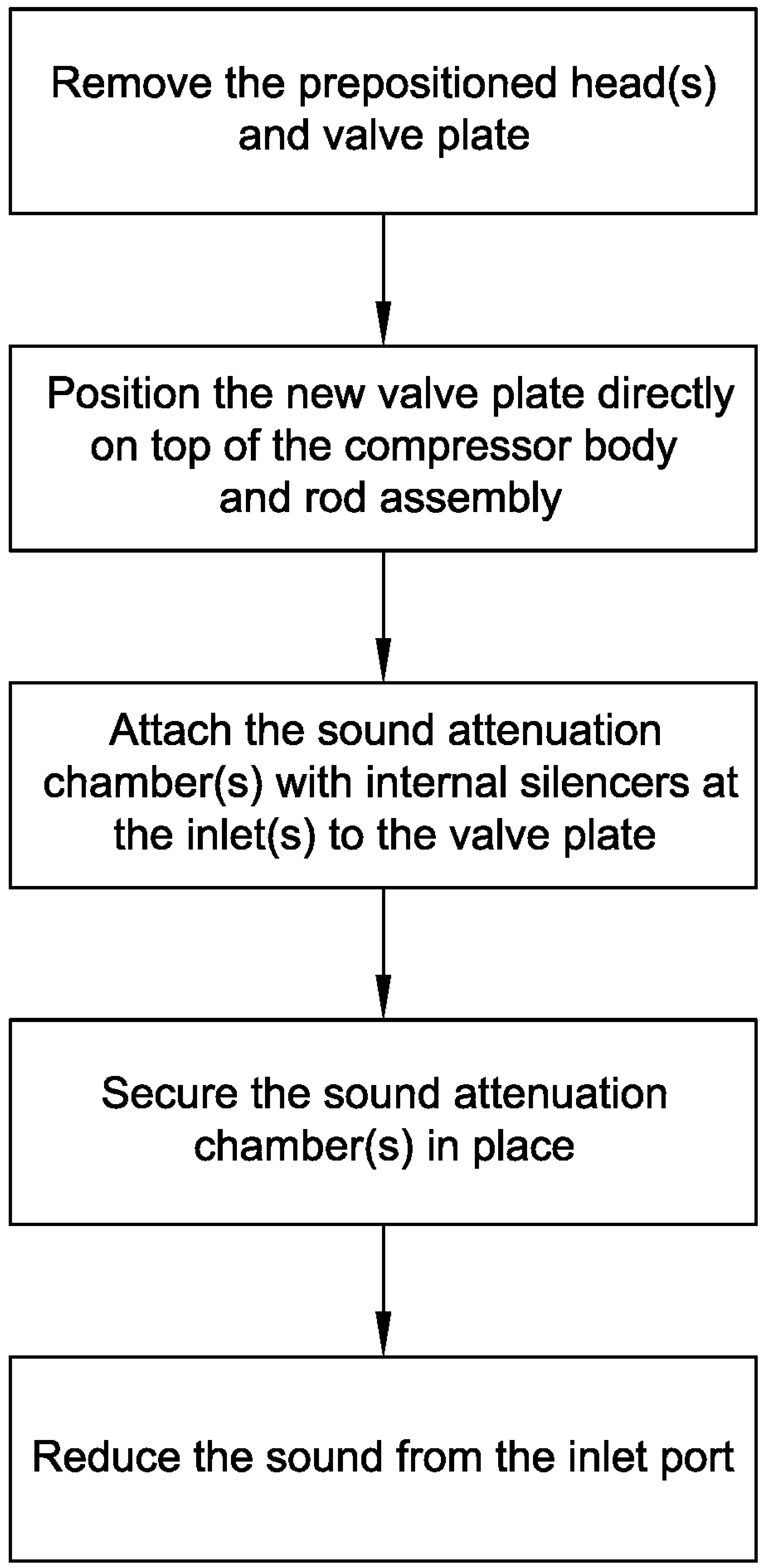
Remove the prepositioned head(s) and valve plate
Position the new valve plate directly on top of the compressor body and rod assembly
Attach the sound attenuation chamber(s) with internal silencers at the inlet(s) to the valve plate
Secure the sound attenuation chamber(s) in place
Reduce the sound from the inlet port

FIGURE 19B

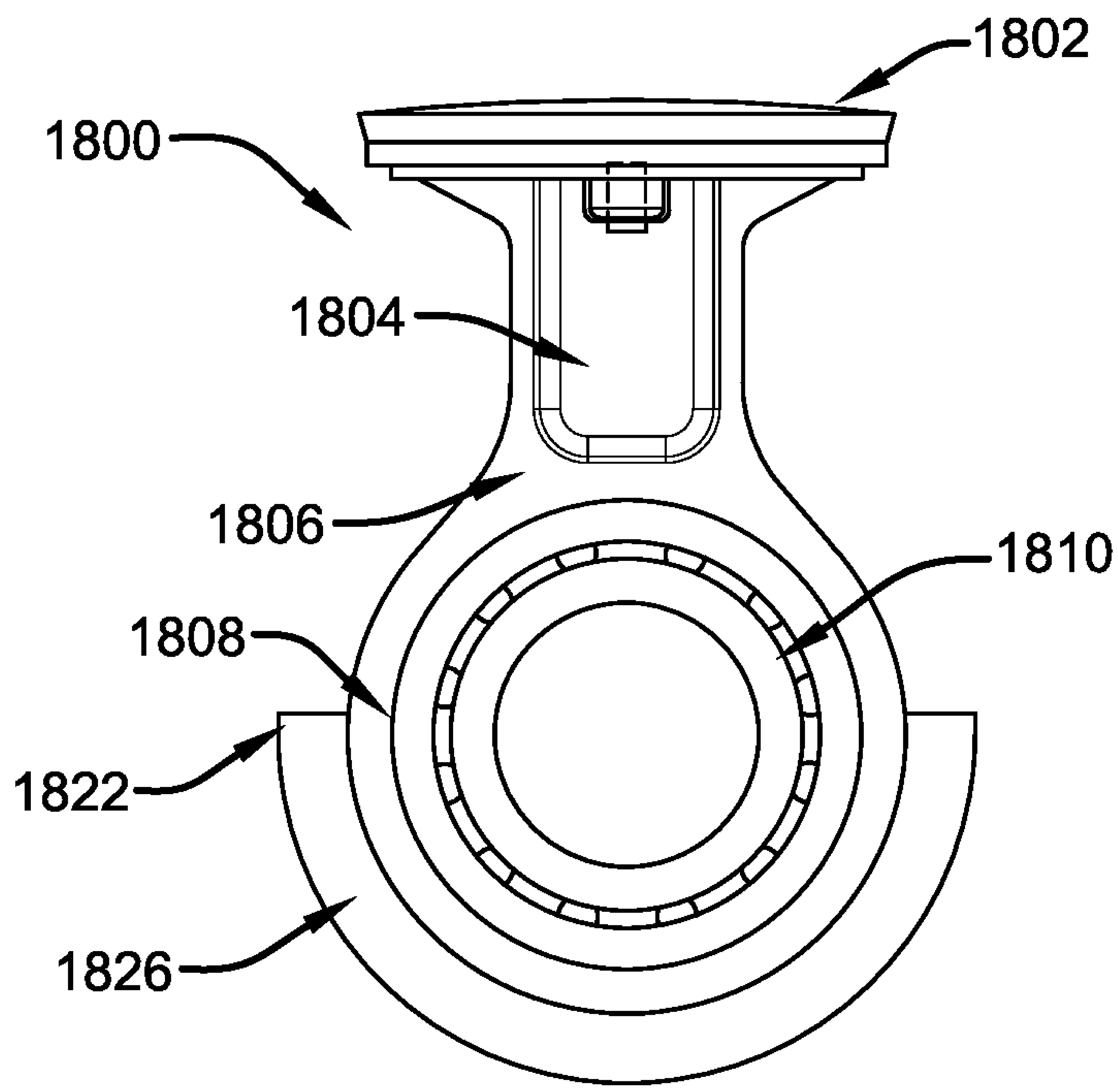

FIGURE 20

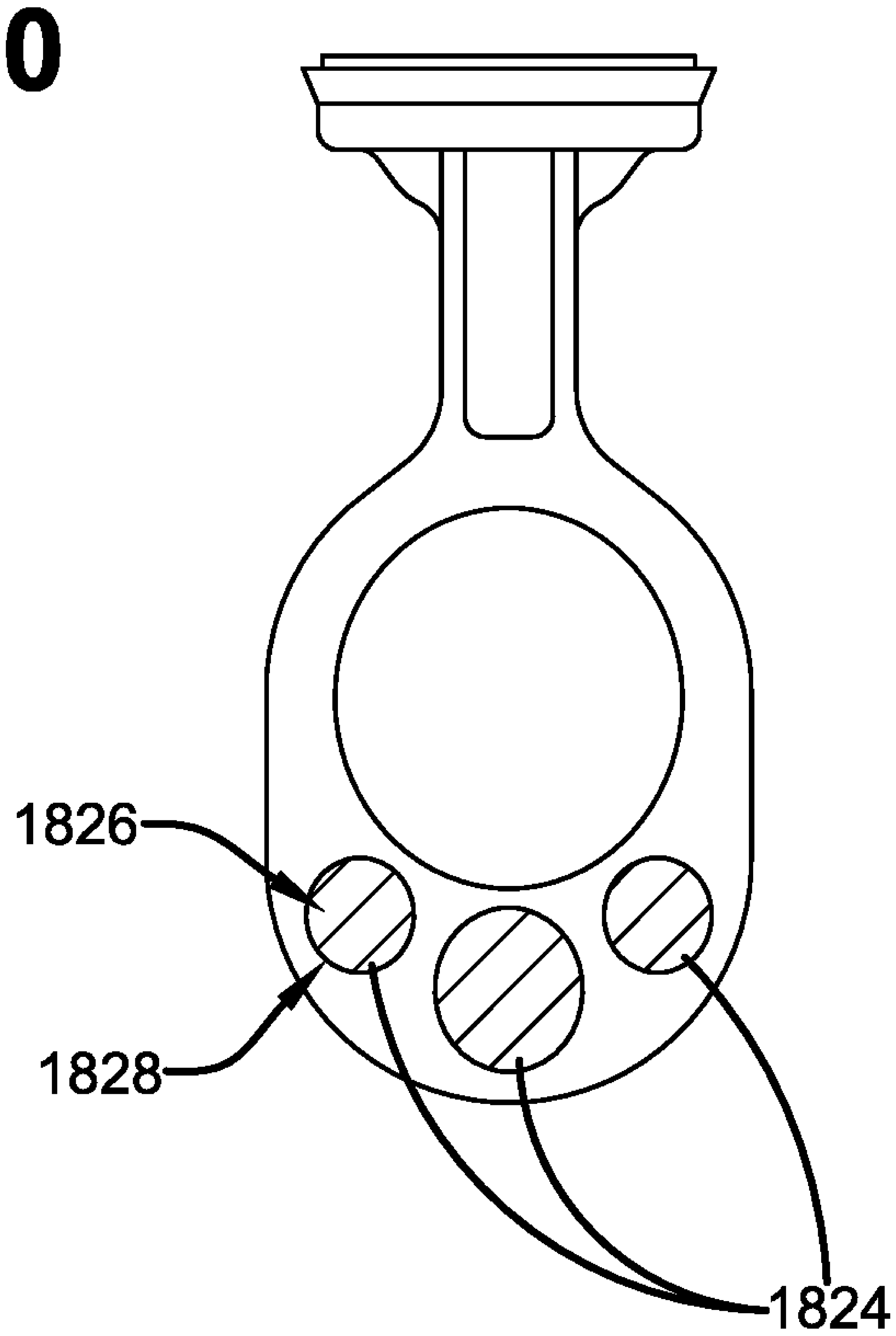

FIGURE 21

SOUND REDUCTION DEVICE FOR ROCKING PISTON PUMPS AND COMPRESSORS

RELATED APPLICATION DATA

This application claims benefit of U.S. Provisional Application No. 62/840,107 filed Apr. 29, 2019, of which is incorporated herein by reference.

BACKGROUND

Sound attenuation and vibration reduction are desired for rocking piston vacuum pumps and compressors. In medical and dental applications, multiple pieces of equipment may be in the same proximate location. As multiple pieces of equipment are used, the decibel level may increase. After reaching a certain decibel level, sound in a room may become distracting. Discussion between a health care provider and patient difficult. Further, the noise may cause feelings of uneasiness if a patient is anxious. As such, reducing noise produced by rocking piston vacuum pumps and rocking pistons in medical and dental applications is desired.

SUMMARY

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key factors or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

A rocking piston vacuum pump or compressor may have a sound attenuation chamber. The chamber may have a first silencer disposed therein. A second silencer may be disposed in series relative to the first silencer and may be disposed externally of the sound attenuation chamber.

To the accomplishment of the foregoing and related ends, the following description and annexed drawings set forth certain illustrative aspects and implementations. These are indicative of but a few of the various ways in which one or more aspects may be employed. Other aspects, advantages and novel features of the disclosure will become apparent from the following detailed description when considered in conjunction with the annexed drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

What is disclosed herein may take physical form in certain parts and arrangement of parts, and will be described in detail in this specification and illustrated in the accompanying drawings which form a part hereof and wherein:

FIG. **1** is a perspective view of a disclosed dual cylinder rocking piston compressor.

FIG. **2** is an exploded view of the compressor shown in FIG. **1**.

FIG. **3**A is top view of the valve plate assembly of the compressor shown in FIGS. **1** and **2**.

FIG. **3**B is bottom view of the valve plate assembly of the compressor shown in FIGS. **1** and **2**.

FIG. **4** is an exploded view of the valve plate assembly shown in FIGS. **3**A and **3**B.

FIG. **5**A is a sectional view taken substantially along lines **5**A'-**5**A' of FIGS. **5**B and **5**A"-**5**A" of FIG. **5**C.

FIG. **5**B is a sectional view taken substantially along line **5**B-**5**B of FIG. **5**A.

FIG. **5**C is a sectional view taken substantially along line **5**C-**5**C of FIG. **5**A.

FIGS. **6**A and **6**B are perspective views of a disclosed single cylinder rocking piston compressor with multiple intake and exhaust ports for multiple configurations.

FIG. **7** an exploded view of the compressor shown in FIG. **6**.

FIG. **8**A is top view of the valve plate assembly of the compressor shown in FIGS. **6**-**7**.

FIG. **8**B is bottom view of the valve plate assembly of the compressor shown in FIGS. **6**-**7**.

FIG. **9** is an exploded view of the valve plate assembly shown in FIGS. **8**A and **8**B.

FIG. **10**A is a sectional view taken substantially along lines **10**A'-**10**A' of FIGS. **10**B and **10**A"-**10**A" of FIG. **10**C.

FIG. **10**B is a sectional view taken substantially along line **10**B-**10**B of FIG. **10**A.

FIG. **10**C is a sectional view taken substantially along line **10**C-**10**C of FIG. **10**A.

FIG. **11** graphically illustrates a sound performance comparison of the disclosed dual cylinder rocking piston compressor vs. a prior art dual cylinder rocking piston compressor with the inlet and outlet plumbed away.

FIG. **12** is a perspective view of another implementation of a dual cylinder rocking piston vacuum pump.

FIG. **13** is a left side view of FIG. **12**.

FIG. **14** is a perspective view of FIG. **12**.

FIG. **15**A is another perspective view of the rocking piston vacuum pump shown in

FIG. **12**.

FIG. **15**B is a perspective view of the rocking piston vacuum pump shown in FIG. **12**.

FIG. **16**A is a perspective view of a sound attenuation chamber.

FIG. **16**B is a side section view of the implementation shown in FIG. **12**.

FIG. **16**C is a front section view showing a first phase of the implementation shown in FIG. **12**.

FIG. **16**D is a front section view showing a second phase of the implementation shown in FIG. **12**.

FIG. **16**E is a front section view showing a third phase of the implementation shown in FIG. **12**.

FIG. **17** is an exploded view of one example implementation of a sound attenuation chamber for a vacuum application.

FIG. **18** is an exploded view of one example implementation of a sound attenuation chamber for a pressure application.

FIG. **19**A is a flow chart illustrating assembly of the sound attenuation chamber for an example vacuum application.

FIG. **19**B is a flow chart illustrating assembly of the sound attenuation chamber for an example pressure application.

FIG. **20** is a front view of a rod assembly.

FIG. **21** is another front view of a rod assembly.

It should be understood that the drawings are not necessarily to scale and that the disclosed embodiments are sometimes illustrated diagrammatically and in partial views. In certain instances, details which are not necessary for an understanding of the disclosed methods and apparatuses or which render other details difficult to perceive may have been omitted. It should be understood, of course, that this disclosure is not limited to the particular embodiments illustrated herein.

DETAILED DESCRIPTION

Prior art FIGS. **1**-**11** represent a dual cylinder rocking piston-type compressor, as illustrated and described in

FIGS. **1-11** of U.S. Pat. No. 9,863,412. FIG. **1** illustrates a disclosed dual cylinder rocking piston-type compressor **20** with two heads **21**, **22** that are mounted onto a valve plate body **23** that may include two distinct valve plates **24**, **25** that may be coupled together by a crossover passageway housing **26**. The two valve plates **24**, **25** and crossover passageway housing **26** may be cast together as a single part or individual valve plates **24**, **25** may be employed with conduits serving as the crossover passageways (not shown). For example, stiff or flexible tubes may be employed for the intake and exhaust crossover passageways as explained below. In the embodiment shown in FIG. **1**, each head **21**, **22** slopes towards its respective valve plate **24**, **25** respectively as each head **21**, **22** extends towards the crossover passageway housing **26**. It has been found that this sloping feature of the heads **21**, **22** provides for improved flow through the compressor **20** for quieter operation.

Referring to FIGS. **1** and **2**, each valve plate **24**, **25** may cover a cylinder **27**, **28** respectively with a seal **31**, **32** that may be sandwiched between each cylinder **27**, **28** and a slot **33**, **34** disposed on the underside **35**, **36** of each valve plate **24**, **25** as shown in FIG. **3**B. As shown in FIG. **2**, each head may include four ports **37**, **38**, **40***a*, **40***b* (head **21**) and **39**, **41**, **40***c*, **40***d* (head **22**). Only a single port is needed for an intake and only a single port is needed for an exhaust but more than one intake and more than one exhaust may be employed. Therefore, the plurality of ports **37**, **38**, **40***a*, **40***b*, **39**, **41**, **40***c*, **40***d* enables the user to employ the compressor **20** in a variety of configurations, as will be apparent to those skilled in the art. In the specific configuration illustrated in FIGS. **1-5**C, any one or more of the ports **37**, **40***a*, **40***c*, **41** may serve as intake ports (or intakes) and any one or more of the ports **38**, **40***b*, **39**, **40***d* may serve as exhaust ports (or exhausts). However, in the illustrated configuration, the ports **40***a*, **40***c* and **41** are plugged while the port **37** is unplugged and therefore the port **37** serves as a single intake for the compressor **20**. Further, because the ports **38**, **40***b*, **40***d* are plugged while the port **39** is unplugged, the port **39** serves as a single exhaust for the compressor in the configuration illustrated in FIGS. **1-5**C. However, as shown in FIGS. **5**B and **5**C, the flow path may be easily reversed by removing the plugs **115**, **116** from the ports **38**, **41** and placing the plugs **115**, **116** in the ports **37**, **39** thereby enabling the port **41** to serve as the intake and the port **38** to serve as the exhaust (assuming that the side ports **40***a*, **40***b*, **40***c*, **40***d* are plugged). Additionally, the intake and exhaust sides may be reversed by switching the positions of the outlet valves **71**, **72** and the inlet valves **82**, **83** (see FIGS. **3**A-**3**B). Thus, the compressor **20** is capable of multiple configurations.

As shown in FIGS. **2** and **5**B, the valve plates **24**, **25** may each include a slot **42**, **44** that each may define intake chambers **87**, **88** with the heads **21**, **22** respectively. Each valve plate **24**, **25** may also include slots **43**, **45** that each may define exhaust chambers **89**, **90** with the heads **21**, **22** respectively as shown in FIG. **5**C. The slots **42-45** may each accommodate a dedicated seal **46**, **47**, **48**, **49** respectively (FIG. **2**). The intake chambers **87**, **88** and exhaust chambers **89**, **90** along with the various sound attenuation chambers **91**, **93**, **94**, **96**, **97**, **99**, **101**, **103** will be described in greater detail below.

Returning to FIG. **2**, each cylinder **27**, **28** may be disposed within a housing **51**, **52** that may be disposed on either side of a motor **53** which rotates the drive shaft **54**. The drive shaft **54** may pass through bearings **55**, **56** before being coupled to the rocking pistons assemblies **57**, **58** which are coupled to the drive shaft **54** by the engagement of a set screw (not shown) extending from the rocking piston assemblies **57**, **58** to flats or slots disposed on the motor shaft (only one of which is shown at **59** in FIG. **2**). The reader will note from FIG. **2** that the rocking piston assemblies **57**, **58** are 180. degree out of phase with each other, meaning that when one piston assembly **57** is performing an exhaust stroke, the other piston assembly **58** is performing an intake stroke and vice versa. Each rocking piston assembly **57**, **58** may include piston heads **62**, **63** that are slidably and sealably received within the cylinders **27**, **28** respectively. Fans **65**, **66** may be disposed between the pistons **57**, **58** and the ventilated covers **66**, **67** respectively for cooling purposes.

The top and bottom sides of the valve plate body **23** and the two valve plates **24**, **25** are illustrated in FIGS. **3**A-**3**B respectively. FIG. **3**A shows the inlet **68** of the valve plate **24** which leads to the cylinder **27** while FIG. **3**B shows the inlet valve **82** of the valve plate **24** disposed beneath the inlet **68** and within an upper portion of the cylinder **27**. Similarly, FIG. **3**A shows the inlet **69** of the valve plate **25** which leads to the cylinder **28** while FIG. **3**B shows the inlet valve **83** disposed beneath the inlet **69** and within an upper portion of the cylinder **28**. FIG. **3**A also shows the exhaust valve **71** for the valve plate **24** and the cylinder **27** as well as the exhaust valve **72** for the valve plate **25** and the cylinder **28**. FIG. **3**A further shows an inlet **74** of the intake crossover passageway **78** (FIGS. **3**B and **5**B) as well as an outlet **75** of the intake crossover passageway **78**. FIG. **3**A also shows an inlet **76** of the exhaust crossover passageway **79** (FIGS. **3**B and **5**C) and an outlet **77** of the exhaust crossover passageway **79**.

FIG. **3**B illustrates the crossover passageway housing **26** for the intake and exhaust crossover passageways **78**, **79**. FIG. **3**B also shows the inlet valve **82** disposed beneath the inlet **68** that leads to the cylinder **27** and the inlet valve **83** disposed beneath the inlet **69** that leads to the cylinder **28**. An exploded view of the valve plate body **23**, the exhaust valve **71**, the inlet valve **82**, and the inlet valve **83** is provided in FIG. **4**. The plugs **85**, **86** seal one end of each crossover passageway **78**, **79** respectively as shown in FIGS. **5**B-**5**C.

FIGS. **5**A-**5**C illustrate the flow of air or gas through the chambers **87-90**, **91**, **93-94**, **96**, **97**, **99**, **101**, **103** that are defined by the valve plate body **23** and the heads **21**, **22**. As noted above and shown in FIGS. **5**B and **5**C, the first and second valve plates **24**, **25** and the heads **21**, **22** may define first and second intake chambers **87**, **88** respectively and first and second exhaust chambers **89**, **90** respectively. The first and second intake chambers **87**, **88** and the first and second exhaust chambers **89**, **90** may be in communication with one or more sound attenuation chambers **91**, **93** (intake chamber **87**), **94**, **96** (intake chamber **88**), **97**, **99** (exhaust chamber **89**) and **101**, **103** (exhaust chamber **90**) via the baffles **105-112** as best seen in FIG. **5**A.

As shown in FIG. **5**B, air or gas enters the compressor **20** through the intake **37** before it passes through the sound attenuation chamber **91** and past the baffle **105** before it enters the intake chamber **87**. The air or gas flows from the intake chamber **87**, past the baffle **106** before entering the sound attenuation chamber **93** and the crossover passageway inlet **74**, which directs the air or gas into the crossover passageway **78**. The crossover passageway outlet **75** permits said air or gas to flow from the crossover passageway **78** through the sound attenuation chamber **94**, past the baffle **107** and into the other intake chamber **88**. As the air or gas flows through the intake side of the compressor **20**, it is drawn downward through the inlets **68**, **69** and into the cylinders **27**, **28** where it is compressed.

Conversely, as shown in FIG. **5**C, air exits the compressor through the outlets **80**, **81** before entering the exhaust chambers **89**, **90**. The crossover passageway inlet **76** receives air or gas from the exhaust chamber **89** after it passes the baffle **110** and after it passes through the sound attenuation chamber **99** before it is directed into the crossover passageway **79**. The outlet **77** communicates the air or gas from the crossover passageway **79** into the sound attenuation chamber **101**, past the baffle **111** and into the exhaust chamber **90**. The air or gas then passes the baffle **112**, proceeds through the sound attenuation chamber **103** and exits the compressor **20** through the exhaust port **39**.

The additional port **41** may be sealed by the plug **115** and the additional port **38** may be sealed by the plug **116**. However, as noted above, the direction of the flow may be reversed by using the port **41** as a single intake and the port **38** as a single exhaust. The side ports **40***a*, **40***b*, **40***c*, **40***d* may also be plugged, used as auxiliary intakes (ports **40***a*, **40***b*), auxiliary exhausts (ports **40***c*, **40***d*) or as single intakes or exhausts, depending on the desired configuration. As will be apparent to those skilled in the art, multiple configurations are available and an exhaustive list need not be mentioned here.

Still referring to FIGS. **5**B-**5**C, the crossover passageways **78**, **79** may be drilled and plugs **85**, **86** may be used to seal the open ends of the crossover passageways caused by the drilling operation.

The flow through the compressor **20** for the illustrated configuration may be described in connection with FIGS. **5**A-**5**C. The first intake chamber **87** may be a sound attenuation chamber itself and may be in communication with one or more sound attenuation chambers **91**, **93**. Gas/air flows through the intake port **37** and into the sound attenuation chamber **91** before passing the baffle **105** and entering the intake chamber **87** before passing the baffle **106** and entering the sound attenuation chamber **93**. The air/gas then proceeds through the inlet **74** to the crossover passageway **78** before exiting through the outlet **75** and entering the sound attenuation chamber **94**. The air or gas passes the baffle **107** before reaching the second intake chamber **88**. The intake chamber **88** may also be in communication with the sound attenuation chamber **96** in addition to the sound attenuation chamber **94**. In the first intake chamber **87**, part of the air/gas proceeds through the inlet **68** and past the inlet valve **82** before it is compressed in the cylinder **27**. In the second intake chamber **88**, part of the air/gas also proceeds through the inlet **69** and past the inlet valve **83** before it is compressed in the cylinder **28**.

After the air/gas is compressed in the cylinder **27**, it passes upward through the outlet **80** and exhaust valve **71** and into the first exhaust chamber **89**. The air then proceeds past the baffle **110**, through the sound attenuation chamber **99** and through the inlet **76** to the crossover passageway **79** before exiting the crossover passageway through the outlet **77** and entering the sound attenuation chamber **101**. The air/gas then passes the baffle **111** before entering the second exhaust chamber **90**. Additional air/gas exits the cylinder **28** through the outlet **81** and exhaust valve **72** before entering the second exhaust chamber **90** and passing the baffle **112** as it enters the sound attenuation chamber **103** before it exits through the exhaust port **39**.

As air/gas enters the intake **37** and expands in the sound attenuation chamber **91** before it is compressed as it passes the baffle **105**. The air/gas expands again in the larger intake chamber **87** (see FIG. **5**A). The increases and decreases in volume and/or pressure as the air passes through the intake port **37**, through the sound attenuation chamber **91**, past the baffle **105** and into the larger intake chamber **87** provides a sound attenuation effect. The air/gas is then compressed again as it proceeds past the baffle **106** before expanding as it proceeds through the sound attenuation chamber **93** and onto the inlet **74**. In addition to the sound attenuation provide by the chamber **93**, the cross-sectional diameter of the crossover passageway **78** is larger than the minimum diameter of the inlet **74**, which causes the air/gas to expand again thereby providing the crossover passageway **78** with sound attenuation effects as well. As the air proceeds through the narrow portion of the outlet **75**, it expands as it enters the sound attenuation chamber **94**. As air passes the baffle **107**, it is compressed again before entering the large intake chamber **88**, which also provides a sound attenuation effect before the air/gas enters the cylinder **28** through the inlet **69**. The valve plate **25** may include the baffle **108** to form a sound attenuation chamber **96** when the additional port **41** is used as the intake.

Similarly, referring to FIG. **5**C, as air exits the cylinder **27**, it passes through the exhaust valve **71** and expands in the exhaust chamber **89** before being compressed as it flows past the baffle **110** before expanding yet again as it enters the sound attenuation chamber **99**. Then, the air/gas passes through the relatively narrow inlet **76** and into the crossover passageway **79** which has a larger diameter than the minimum diameter of the inlet **76** thereby providing a sound attenuation effect for the crossover passageway **79**. The air/gas then contracts as it enters the outlet **77** before expanding as it enters the sound attenuation chamber **101** before being compressed as it passes the baffle **111**. The air/gas then expands again as it enters the exhaust chamber **90**. Air/gas exits the cylinder **28** through the exhaust valve **72** and into the exhaust chamber **90** before being compressed as it passes the baffle **112** and enters the final sound attenuation chamber **103** before exiting through the exhaust port **39**.

Without being bound by theory, it is believed that the various disclosed sound attenuation chambers, intake chambers exhaust chambers and sloping heads, in combination with the baffles, provide expansion and compression of the air/gas as it proceeds through the sound attenuation chambers (and intake and exhaust chambers) and past the baffles before exiting through the exhaust port provides significant sound attenuation properties. These improved sound attenuation properties are presented in FIG. **11** where the line **300** represents the sound level of a conventional dual cylinder rocking piston type compressor and the line **301** represents the sound level of the disclosed dual cylinder rocking piston-type compressor **20**.

A single cylinder rocking piston compressor **120** is illustrated in FIGS. **6**A-**10**C. The compressor **120** may comprise a head **121** that covers a valve plate **124**. The head **121** may include a plurality of ports **137**, **138**, **139**, **141**, **140***a*, **140***b*, **140***c*, **140***d*. Like the compressor **20** shown in FIGS. **1**-**5**C, the head **121** slopes towards the valve plate **124** as the head **121** extends from one end of the valve plate **124** to the other end of the valve plate **124**. The sloping configuration of the head **121** results in a reduction in the size of the chamber(s) defined by the head **121** and valve plate **124** for improved flow and quieter operation of the compressor **120**.

In the configuration illustrated, all of the ports except the intake **137** and exhaust **139** are plugged, but the ports **140***a*, **140***c* and **141** could also serve as intakes and the ports **140***b*, **140***d*, and **138** could also serve as exhausts. Further, the intake and exhaust sides of the compressor **120** may be reversed in addition to the flow direction, as explained above in connection with the compressor **20** of FIGS. **1**-**5**C. Thus, the compressor **120** may assume multiple configurations like the compressor **20** discussed above and each configuration need not be listed here.

To reverse the flow direction of the compressor **120**, the plug **215** can be moved from the intake port **141** to seal the exhaust port **139** and the plug **216** can be removed from the exhaust port **138** to plug the intake port **137**. That arrangement (not shown in FIG. **6**A, **6**B or **7**) would establish the intake at the port **141** and the exhaust at the port **138**. As noted above, with the configuration of the inlet valve **171** (FIG. **8**A) and the exhaust valve **182** (FIG. **8**B), the port **140***a* may also be used as an intake and/or the port **140***c* may be used as an exhaust. Further, the ports **140***b* may be used as an intake and/or the port **140***d* may be used as an exhaust (and vice versa is the positions of the valves **171**, **182** are switched). Use of the ports **140***b*, **140***d* as the intake and exhaust may lower the profile of the compressor **120** when various plumbing accessories such as intake and exhaust filters and mufflers are attached. As an alternate construction (not shown) of valve plate body **23** used in the construction of compressor **20** (dual cylinder compressor), two valve plates **124** may have ports **140***b* and **140***d* modified to receive separate intake and exhaust chamber passageways of various construction methods, thereby providing communication between each valve plate. This alternate construction provides flexibility for future dual cylinder compressor configurations where a longer motor **53** with more power may be required to further expand the performance range of the compressor.

Turning to FIG. **7**, dedicated seals **146**, **147** may be accommodated in the channels **142**, **143** respectively for purposes of defining an intake chamber **187** and an exhaust chamber **189** and the related sound attenuation chambers **191**, **193**, **201**, **203** (see FIGS. **10**A-**10**C). Still referring to FIG. **7**, the valve plate **124** may be used to cover a cylinder **127**. An O-ring seal **131** may be sandwiched between the cylinder **127** and the underside of the valve plate **124**. The compressor motor **153** may rotate a drive shaft **154**, which may pass through a bearing **155** before it passes through the rocking piston assembly **158** and the fan **166**. The drive shaft **154** may also pass through an additional ring **156** and a bushing **217**. The motor may be partially accommodated in and supported by the main housing **152** and a ventilated end housing **167**. A ventilated cover **166** may be coupled to the main housing **152** for purposes of protecting the fan **166**. The bearing **166** may be covered by an end cap **218**. Various fasteners are shown at **220**, **221** for purposes of holding the compressor **120** together.

Turning to FIGS. **8**A-**8**B, top and bottoms views of the valve plate **124** are shown. The valve plate **124** may include slots or grooves **142**, **143** for purposes of accommodating the seals **146**, **147** respectively (see FIG. **7**). An exhaust valve **171** may cover an outlet **180**. An intake valve **82** covers the underside of the inlet **168** shown in FIG. **8**A while the exhaust valve **171** covers the upper side of the outlet **180**. A slot or groove **133** accommodates the O-ring **131** shown in FIG. **7**.

FIG. **9** is an exploded view of the valve plate **124**, exhaust valve **171**, and intake valve **182**. FIGS. **10**A-**10**C illustrates the air/gas flow through the compressor **120**. Air enters through the intake port **137** and passes into the intake chamber **187**. The intake chamber **187** may be in communication with a plurality of sound attenuation chambers **191**, **193**. The sound attenuation chambers **191**, **193** may be defined by the baffles **205**, **206** as well as the head **121** and valve plate **124**. Further, as discussed above in connection with the compressor **20** illustrated in FIGS. **1**-**5**C, successive

expansions and contractions of the volume or cross-sectional area through which the air/gas passes provides sound attenuation. Therefore, as air/gas enters the intake port **137**, it expands into the sound attenuation chamber **191** before it is compressed again as it passes the baffle **205**. The air/gas is then expanded again as it enters the large intake chamber **187**. The gas/air exits the intake chamber **187** through the inlet **168** as it passes through the intake valve **182** (FIG. **10**B). The sound attenuation chamber **193** and baffle **206** assists with sound attenuation, but also acts as a sound attenuation chamber when the additional port **141** is used as the intake.

Turning to FIG. **10**C, air/gas exits the cylinder **127** through the outlet **180** and past the exhaust valve **171** before it enters the exhaust chamber **189**. Similar to the intake chamber **187**, the exhaust chamber **189** may be in communication with a plurality of sound attenuation chambers **201**, **203** that may be defined by the baffles **211**, **212**, the head **121** and valve plate **124**. As air/gas passes upward through the outlet **180** and past the exhaust valve **171**, it expands into the large exhaust chamber **189**. As the air/gas moves toward the exhaust port **139**, it is compressed as it passes the baffle **211** before it is expanded again in the sound attenuation chamber **203** prior to exiting the compressor **120** through the exhaust **139**. The baffle **212** and the sound attenuation chamber **201** provide sound attenuation benefits, but are used primarily when the additional port **141** serves as the exhaust.

As suggested above in regard to the compressor **20** of FIGS. **1**-**5**C, without being bound by theory, it is believed that the successive expansions and contractions of the air or gas passing through the compressor **120** provides significant sound attenuation as graphically illustrated in FIG. **11** even though the curve **301** was generated with a dual rocking piston compressor **20** as opposed to a single cylinder rocking piston compressor **120**.

With reference to FIGS. **12**-**19** another implementation of a sound attenuation assembly **1200** is described. FIGS. **12**-**19** show example implementations of the sound attenuation assembly utilized for vacuum applications and pressure applications that may apply to pumps and/or compressors. Pressure applications and vacuum applications may utilize a single head or a dual head. In one example implementation, pressure applications may utilize a silencer at an inlet of the sound attenuation chamber **1200**. In another example implementation, vacuum applications may utilize a silencer at an exhaust or outlet of the sound attenuation chamber.

The sound attenuation assembly **1200** may be utilized with a compressor or a vacuum pump. In another implementation, the sound attenuation assembly **1200** may be utilized with a rocking piston compressor or a rocking piston vacuum pump. In one implementation, the sound attenuation assembly may be selectably removable from the head of the vacuum pump or compressor. The sound attenuation assembly may be sold as a kit to retrofit onto existing compressors and pumps. In one example implementation, by disposing two mufflers, as described below in series, decibel levels may be reduced. In one implementation sound levels may be reduced from about 69 dB(A) (20 Sones) to about 54 dB(A) (9.6 Sones) consistently, when intake air is plumbed away from a sound room (not shown) and the outlet exhausts to the atmosphere within the sound room.

As shown in FIG. **12**-**19**, the sound attenuation assembly **1200** may comprise an exhaust sound attenuation chamber **1201**. In one implementation, the sound attenuation chamber **1201** may replace one of the heads of the compressor or pump. The sound attenuation chamber **1201** may comprise one or more ports **1230**. Ports **1230** may be an inlet port **1230***a* or an outlet port **1230***b*. The sound attenuation chamber **1201** may be operably connected to a base **1204**. The sound attenuation chamber **1200** may comprise a first silencer **1210** or muffler. The first silencer **1210** or muffler may be internal. In one implementation, the first silencer **1210** may be a SMC ANA1-02. The internal silencer **1210** may be partially or completely engulfed or surrounded with sound dampening foam **1212**.

The sound dampening foam **1212** may be any foam chosen with sound engineering judgment. By way of non-limiting example, sound dampening foam **1212** may be open-cell foam. The sound dampening foam **1212** may be an insulation material that absorbs multi-frequency noise, minimizes reverberation, improves acoustics, and/or may keep sound from escaping the enclosed area of the sound attenuation chamber **1201**. The sound dampening foam **1212** disposed inside the sound attenuation chamber **1201** may be disposed to adequately surround the internal silencer to minimize sound. For example, small pieces of sound dampening foam **1212** may be disposed in the sound attenuation chamber **1201**. In another nonlimiting example, larger pieces of sound dampening foam **1212** may be disposed in the sound attenuation chamber **1200**. The pieces of sound dampening foam **1212** may be loosely packed or densely packed around the internal silencer. The sound dampening foam **1212** may partially fill or completely fill the sound attenuation chamber **1201**. In another alternative embodiment, the sound dampening foam **1212** is disposed inside the sound attenuation chamber **1200** such that an operator may easily access the internal silencer for repair or replacement. In one implementation, the sound dampening foam **1212** or open-cell foam acts as a sound absorber, which may further reduce the amplitude of air exhaust noise.

With reference to FIGS. **12**-**18**, one example implementation of the sound attenuation assembly **1200** is shown as used with a rocking piston vacuum pump **1100**. The sound attenuation chamber **1201** may be operatively connected to the base **1215**. In one implementation, the sound attenuation chamber **1201** may be operably connected to the rocking piston pump **1100** by way of the base **1215**, which may be a spacer plate **1202**. An o-ring **1203** or other seal may be interposed between the sound attenuation chamber **1201** and the spacer plate **1202**. The spacer plate **1202** may be operably connected to a valve plate **1204**. In one example implementation, the spacer plate **1202** may be operably connected to the valve plate **1204**. The valve plate **1204** may be configured to be proximate a cylinder (previously described). The valve plate **1204** may comprise an inlet and an outlet that are in communication with the cylinder. The spacer plate **1202** may comprise an inlet chamber. An o-ring **1207** or other seal may be interposed between the spacer plate **102** and the valve plate **1204**. The internal silencer **1210** may be mated directly onto or operably connected to the spacer plate **1202**. A second silencer **1220** may be operably connected to the sound attenuation chamber **1201**. The second silencer **1220** may be at least partially external to the sound attenuation chamber **1201** in a vacuum application. The second silencer **1220** may be operably connected to the sound attenuation chamber **1200** through one of the ports **1230** of the sound attenuation chamber **1201**. In another implementation of a vacuum application, the second silencer **1220** may be operably coupled to the exhaust port **1230***b* of the sound attenuation chamber by means of an elbow **1219**. The second silencer **1220** may also be a SMC ANA1-02 silencer. The combination of placing the two silencers **1210**, **1220** in series may produce sound dampening of exhaust air from the pump or compressor with minimal air restriction. The sound dampening foam **1212** may add additional sound reduction. Any open ports **1230** may be closed with a port plug **1232**.

With references to FIGS. **16**A-E, operation of the dual-head rocking piston remains the same as previously described. FIGS. **16**A-E describes one example implementation of air flow for a vacuum application. The sound attenuation chamber **1200** may reduce air exhaust noise. Turning to FIGS. **16**A-**16**E, an example of phases of air from intake to exhaust are shown. FIG. **16**B illustrates intake of atmospheric air filling an air inlet chamber of the spacer plate. Intake of atmospheric air may create suction during the downstroke of a rod. The air passes through the rocking piston compressor as previously described.

After passing through the compressor, the intake atmospheric air passes into an exhaust chamber disposed in the spacer plate. This may occur with a valve limiter during the upstroke of the rod. As such, the exhaust air is routed through the valve limited and then into the exhaust chamber of the spacer plate of the sound attenuation chamber **1200**.

In another implementation, the sound attenuation chamber **1200** may process exhaust air in a plurality of phases to reduce sound. One example of such implementation may process the exhaust air in three phases. As shown in FIG. **16**C, exhaust air may pass into the exhaust chamber or exhaust cavity of the spacer plate. The exhaust air may enter the first silencer **1210** at a first velocity V**1**. The first velocity V**1** may be at a high velocity. Once the exhaust air is in the first silencer **1210**, the exhaust air may be redirected into smaller streams of air that reflect off opposing walls within the silencer. It is believed that as air particles collide with each other, molecular velocity is reduced and the exhaust air is dispersed through small openings throughout the silencer at a second reduced velocity V**2**. Due to the reduced velocity, noise is reduced.

A second phase is shown in FIG. **16**D. When the exhaust air exits the first silencer **1210**, the exhaust air enters the sound attenuation chamber **1200**. Sound dampening foam **1212** may be disposed inside the sound attenuation chamber **1200** as previously described. In one implementation, the sound dampening foam **1212** or open-cell foam acts as a sound absorber, which may further reduce the amplitude of air exhaust noise. By adding this volume of the sound attenuation chamber **1200** in conjunction with the sound dampening foam **1212**, reflections of the noise, i.e. sound waves, weakens and causes a dulled sound effect.

A third phase is shown in FIG. **16**E. After exhaust air expands and fills the sound absorbing foam filled sound attenuation chamber **1200**, exhaust air is then directed to an outlet hole of the sound attenuation chamber **1200**. The second silencer **1220** is operably connected to the side wall of the sound attenuation chamber **1200** by way of the outlet hole. The second silencer **1220** may be positioned in series relative to the first silencer **1210**. The exhaust air may enter the second silencer **1220** at a third velocity V**3**. The third velocity V**3** is less than velocity V**2**, which is less than velocity V**1**. Once the exhaust air is in the second silencer **1220**, the exhaust air may be redirected into smaller streams of air that reflect off opposing walls within the second silencer **1220**. As air particles collide with each other, molecular velocity is reduced and the exhaust air is dispersed through small openings throughout the silencer at a fourth reduced velocity V**4**, which is less than velocity V**3**. Exhaust air may exit the second silencer **1220** and be dispersed into the atmosphere.

In another implementation, the sound attenuation assembly **1200** may be operably connected to a pressure application. In one implementation, the pressure application may be a compressor **1150** or a rocking piston compressor **1150** as shown in FIG. **18**. In one implementation, the compressor or pump in a pressure application **1150** may have dual or single heads. The sound attenuation assembly **1200** may have the first sound attenuation chamber **1201**. It may also comprise a second sound attenuation chamber **1209**. Each sound attenuation chamber **1201**, **1209** may be operably coupled to the base **1215**. In the pressure application, the base **1215** may be the valve plate **1204**. An o-ring **1240**, o-ring gasket or other seal may be utilized to sealingly couple the sound attenuation chamber **1201** to the valve plate **1204**. The valve plate **1204** may be proximate a cylinder. The valve plate **1204** may comprise an inlet and an outlet that are in communication with the cylinder. At least one sound attenuation chamber **1201** may have the first silencer **1210**. The second sound attenuation chamber **1209** may also have a second silencer **1220**. Optionally, additional silencers may be operably coupled to the sound attenuation ports **1230** to further reduce sound. In one example implementation of a pressure application **1150**, the first silencer **1210** may be operably connected to the inlet port **1230***a* of the sound attenuation chamber **1201**.

It should be understood that any number of silencers may be used in connection with the sound attenuation chamber to achieve noise reduction. For larger rocking piston compressors or pumps, two or more internal silencers may be used internally or externally given the application (vacuum or pressure).

With reference to FIGS. **19**A and **19**B, the sound attenuation assembly **1200** may be installed onto a vacuum application **1100**, such as but not limited to a rocking piston vacuum pump **1100** or a pressure application **1150**, such as but not limited to the rocking piston compressor **1150** with the following steps. The propositioned head may be removed. For vacuum model applications, the spacer plate may be positioned proximate the valve plate, for example in an application with the vacuum pump. For pressure model applications, the spacer plate may not be utilized. The sound attenuation chamber may be positioned either to the spacer plate (for vacuum model applications) or the valve plate (for pressure model applications). The sound attenuation may comprise the first silencer disposed therein. For vacuum applications, the first silencer may be operably connected to the exhaust or outlet port **1230***b* of the sound attenuation chamber. For pressure applications, the first silencer may be operably connected to the inlet port **1230***a* of the sound attenuation chamber. The second silencer may be operably connected to one of the exhaust ports of the sound attenuation chamber in a vacuum application. The sound is then reduced during operation of the rocking piston vacuum pump or the rocking piston compressor.

With reference to FIGS. **20** and **21**, another implementation of a rocking piston compressor is illustrated to reduce vibration. The compressor may have a rod assembly **1800** which may be operably connected to the draft shaft **54**, which has been previously described. The rod assembly **1800** may comprise a piston head **1802**, a rod **1804**, and a rod assembly body **1806**. The rod assembly body **1806** may have a bore **1808** for positioning a bearing **1810** therein. The rod assembly **1800** has a center of mass CM. A counterbalance weight **1820** may be disposed on the rod assembly **1800** to move the center of mass from the center of the rod assembly **1800** to a center of the bearing **1810** or bearing bore **1808**. Vibration transmission is minimized from the rod and shaft. It is believed that the exerting forces will be reduced from about 11 Newtons to about 0 Newtons. In one nonlimiting implementation, tungsten may be used to provide the correct amount of mass due to possible space constraints within the compressor.

In one nonlimiting example, the counter balance weight **1820** may be positioned on a lower portion of the rod assembly body **1806**. In one implementation, the counterbalance weight **1820** may be positioned on an exterior surface **1807** of the rod assembly body **1806**. In another implementation, the counterbalance weight **1820** may have an edge **1822**, and the edge **1822** may be disposed concentric with the bearing bore **1808** or below the center of the bearing **1810**. In another implementation, holes **1824** may be bored in the bottom portion of the rod assembly body **1806**, where the holes **1824** may be filled with dense metal **1826**, such as, but not limited to tungsten **1828**. By moving the center of mass to be coincident with the center of the bearing or the bearing bore, vibration may be minimized.

Within applications, such as but not limited to medical and dental system applications, that require little to no vibration, particularly when mounted to a cabinet system. Reducing compresor vibration may also contribute to a longer life cycle of the compressor components and the compressor itself. By positioning the rod assembly's center of mass to be substantially concentric with the center of the bearing bore, dynamic balance becomes more stable when the eccentric is included, resulting in minimizing dynamic forces. In minimizing vibration of the compressor through rod assembly alterations, the compressor will experience less wear and tear.

Finally, the disclose compressors are capable of assuming multiple configurations, including low profile configurations and configurations which may permit the use of a larger motor. The flow direction of the compressors may be easily reversed.

The word "exemplary" is used herein to mean serving as an example, instance or illustration. Any aspect or design described herein as "exemplary" is not necessarily to be construed as advantageous over other aspects or designs. Rather, use of the word exemplary is intended to present concepts in a concrete fashion. As used in this application, the term "or" is intended to mean an inclusive "or" rather than an exclusive "or." That is, unless specified otherwise, or clear from context, "X employs A or B" is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then "X employs A or B" is satisfied under any of the foregoing instances. Further, at least one of A and B and/or the like generally means A or B or both A and B. In addition, the articles "a" and "an" as used in this application and the appended claims may generally be construed to mean "one or more" unless specified otherwise or clear from context to be directed to a singular form.

Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims. Of course, those skilled in the art will recognize many modifications may be made to this configuration without departing from the scope or spirit of the claimed subject matter.

Also, although the disclosure has been shown and described with respect to one or more implementations, equivalent alterations and modifications will occur to others skilled in the art based upon a reading and understanding of this specification and the annexed drawings. The disclosure includes all such modifications and alterations and is limited only by the scope of the following claims. In particular regard to the various functions performed by the above described components (e.g., elements, resources, etc.), the terms used to describe such components are intended to correspond, unless otherwise indicated, to any component which performs the specified function of the described component (e.g., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary implementations of the disclosure.

In addition, while a particular feature of the disclosure may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application. Furthermore, to the extent that the terms “includes,” “having,” “has,” “with,” or variants thereof are used in either the detailed description or the claims, such terms are

The implementations have been described, hereinabove. It will be apparent to those skilled in the art that the above methods and apparatuses may incorporate changes and modifications without departing from the general scope of this invention. It is intended to include all such modifications and alterations in so far as they come within the scope of the appended claims or the equivalents thereof.

What is claimed is:

1. A sound attenuation assembly for a pressure application for a rocking piston compressor or rocking piston pump, the rocking piston compressor or rocking piston pump, comprising:

a first rocking piston assembly operably connected to a first cylinder;

a second rocking piston assembly operably connected to a second cylinder;

a valve plate body comprising a first valve plate coupled to a second valve plate by a crossover passageway, wherein the first valve plate proximate the first cylinder, and wherein the second valve plate proximate the second cylinder;

a first head arranged over the first valve plate and comprising a first intake port and a first exhaust port;

a second head arranged over the second valve plate comprising a second intake port and a second exhaust port;

the sound attenuation chamber assembly, comprising:

a first sound attenuation chamber operably connected to and arranged proximate the first valve plate, the first sound attenuation chamber disposed over the first head;

a second sound attenuation chamber operably connected to and arranged proximate the second valve plate, the second sound attenuation chamber disposed over the second head; and,

a first silencer operably disposed in the first sound attenuation chamber and a second silencer disposed in the second sound attenuation chamber,

wherein the first and second sound attenuation chambers and the first and second silencers are configured to reduce sound for the rocking piston compressor or the rocking piston pump, wherein the first silencer and the second silencer receive air in parallel at the respective intake ports in the pressure application.

2. The sound attenuation assembly of claim **1**, further comprising at least one additional silencer disposed in the first attenuation chamber.

3. The sound attenuation assembly of claim **1**, wherein the first sound attenuation chamber is selectably removable from the first valve plate and the second sound attenuation chamber is selectably removable from the second valve plate.

4. The sound attenuation-assembly of claim **1**, further comprising foam, the foam at least partially engulfing the first silencer.

5. The sound attenuation assembly of claim **1**, further comprising at least one additional silencer disposed in the second sound attenuation chamber.

6. The sound attenuation assembly of claim **1**, wherein the first sound attenuation chamber is sealingly coupled to the first valve plate with an o-ring or gasket and the second sound attenuation chamber is sealingly coupled to the second valve plate with an o-ring or gasket.

7. A sound attenuation assembly for a rocking piston pump or a rocking piston compressor, comprising:

a valve plate proximate a cylinder, the valve plate comprising an inlet and an outlet that are in communication with the cylinder;

a sound attenuation chamber operably connected to the valve plate, the sound attenuation chamber having an inlet port and an outlet port;

a first silencer operably connected to the sound attenuation chamber, wherein the first silencer is operably connected to the inlet port for a pressure application or the first silencer is operably connected to the outlet port for a vacuum application;

a spacer plate interposed between the sound attenuation chamber and the valve plate, wherein the spacer plate defines a chamber for air and is arranged between the sound attenuation chamber and the valve plate; and

an additional valve plate proximate an additional cylinder and coupled to the valve plate by a crossover passageway;

the rocking piston compressor or the rocking piston pump, comprising:

a first rocking piston operably connected to the cylinder; and

a second rocking piston operably connected to the additional cylinder; and

a head arranged over the additional valve plate and comprising a first intake port and a first exhaust port.

8. The sound attenuation assembly of claim **7**, further comprising a second silencer mated onto and disposed external to the spacer plate, wherein the second silencer is in series with the first silencer.

9. The sound attenuation assembly of claim **7**, further comprising sound dampening foam at least partially engulfing the first silencer and at least partially filling the sound attenuation chamber.

10. The sound attenuation assembly of claim **7**, wherein the spacer plate has outer sidewalls arranged directly over outer sidewalls of the valve plate, wherein the outer sidewalls of the spacer plate are arranged directly below outer sidewalls of the sound attenuation chamber, and wherein the spacer plate is sealed to the valve plate and is sealed to the sound attenuation chamber.

11. A method for reducing sound in a rocking piston vacuum pump or rocking piston compressor, comprising the steps of:

removing a prepositioned head from a valve plate;

positioning a spacer plate over the valve plate after removing the prepositioned head;

positioning a sound attenuation chamber to the spacer plate after positioning the spacer plate, the sound attenuation chamber comprising an inlet port and an outlet port;

operably connecting a first silencer to the inlet port for a pressure application or operably the first silencer to the outlet port for a vacuum application; and

reducing sound during operation of the rocking piston vacuum pump or the rocking piston compressor.

12. The method of claim **11**, further comprising the step of operably connecting a second silencer externally to the sound attenuation chamber and in series with the first silencer.

13. The method of claim **11**, the valve plate configured to be proximate a cylinder, the valve plate including an inlet and an outlet that are in communication with the cylinder.

14. The method of claim **11**, wherein the first silencer is mated directly onto the spacer plate.

15. A sound attenuation assembly for a rocking piston pump or a rocking piston compressor, comprising: a valve plate proximate a cylinder, the valve plate comprising an inlet and an outlet that are in communication with the cylinder; a sound attenuation chamber operably connected to the valve plate, the sound attenuation chamber having an inlet port and an outlet port; a first silencer operably connected to the sound attenuation chamber, wherein the first silencer is operably connected to the inlet port for a pressure application or the first silencer is operably connected to the outlet port for a vacuum application; a spacer plate interposed between the sound attenuation chamber and the valve plate, wherein the spacer plate defines a chamber for air and is arranged between the sound attenuation chamber and the valve plate; an additional valve plate proximate an additional cylinder and coupled to the valve plate by a crossover passageway, and a head arranged over the additional valve plate and comprising a first intake port and a first exhaust port, wherein the sound attenuation chamber is arranged above a topmost surface of the head.

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